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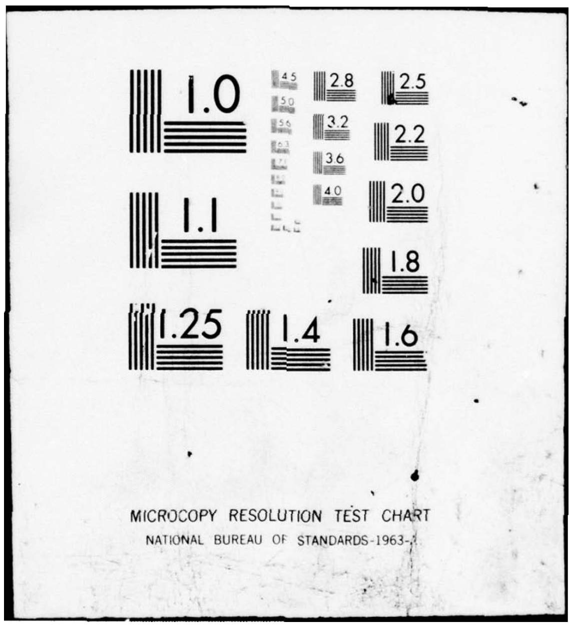
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AFAL-TR-78-176

INFRARED TARGET/BACKGROUND DISCRIMINATION - BACKGROUND SPECTRAL MODELING

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November 1978
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Final Report for Period June 1977-October 1978

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This technical report has been reviewed and is approved for publication.

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This report discusses the development of statistical models for signals in the background radiance distribution. Techniques for analyzing multispectral line scan data are developed and demonstrated on background data obtained by the Environmental Research Institute of Michigan. Since the scope of the data is not adequate to provide statistically significant results, the conclusions are restricted to a presentation of the analytic method and a discussion of its potential applicability to more realistic data sets.

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PREFACE

The work described in this report was supported by the Passive ECM Branch of the Electronic Warfare Division of the Air Force Avionics Laboratory as part of its Infrared Warning Receiver Development Program. E.E. Wisniewski and R.B. Sanderson were project engineers at different times during the course of the effort.

The data tapes were provided through the courtesy of Dr. Lowell Wilkins and Dr. Jon Wunderlich of the Naval Weapons Center, China Lake, CA. J.R. Maxwell of the Environmental Research Institute of Michigan provided assistance in using and interpreting the tapes.

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SECTION I. INTRODUCTION

Infrared threat warning receivers offer the attractive possibility of improving aircraft survivability through sensing and detection of emitted and/or reflected radiative threat characteristics. This is especially true where the threat uses passive sensing and homing techniques. Even in the absence of active energy from the threat, the IR warning receiver can detect thermal radiation from the rocket plume or from the elevated temperature of a threat vehicle.

The major problem encountered in the development of an IR warning receiver is due to the competing requirements for high sensitivity and low false alarm rate. Thus infrared warning receivers have had limited utilization due to an inability to discriminate against certain backgrounds which produce false alarms. Current and past methods for solving this problem have required the use of more and more sophisticated discrimination techniques which rely on spectral, spatial and temporal characteristic differences between the threat and its background. Backgrounds which produce high false alarm rates have been identified and programs are underway to provide high resolution spectral measurements and models for more effectively discriminating against these background sources.

Little is known about the probability of encountering the identified classes of high radiance background sources. Thus it was the objective of this effort to develop statistical descriptors for background data using available measurement data. The descriptors were to show interdependence of radiance and area for the background data.

Much of the existing background data has been gathered in reconnaissance efforts utilizing banded radiometric scanners; thus, no high resolution spectral data were available for analysis at this time. The inclusion of spectral dependence offers another dimension for comparison and discrimination and could be incorporated at a later time. Correlation between spectral bands for existing data could be accomplished and has been investigated by others. [1] Thus the major emphasis for this effort was on amplitude and area statistics for individual records in a given spectral band.

The following specific tasks are listed in the statement of work.

1.1 Develop a basis for characterization of background sources such as stack burn-off, stack emissions, glint off water, etc., which will provide their radiant emittance and solar reflectance profiles in the 4.3 micrometer (CO_2 band) spectral region.

1.2 Reduce AFAL furnished multispectral data to:

1.2.1 Identify and classify specific background sources with 4.3 micrometer spectral signatures which are indicative of source temperatures well above the ambient.

1.2.1.1 For each class of these sources determine the distribution of the characterizing parameter, e.g., radiant emittance, spatial profile, etc.

1.2.1.2 Develop statistics describing the composition and distribution of the background sources in various scenarios.

1.2.2 Develop iso-radiant emittance terrain models (similar to

SECTION II. THEORETICAL DEVELOPMENT FOR STATISTICAL DESCRIPTION OF BACKGROUND RADIANCES

The essential features for modeling background radiances measured by a sensor and relating that radiance to false target probability are shown in Figure 1.

A statistical model for evaluating false detection probability for backgrounds is best developed in terms of conditional probabilities. The single glimpse probability of detection for a false target is given by

$$P = P_1 \cdot P_2 \cdot P_3 \tag{1}$$

where P = single glimpse detection probability for a false target

P_1 = probability of detection given that the false target is in the sensor field-of-view

P_2 = probability the false target is in the sensor field-of-view given the false target is within the scene

P_3 = probability the false target is within the scene.

P_3 may be further developed as a conditional probability in terms of general scene categories such as urban, suburban, industrial, forest, desert, etc.

P_1 depends primarily on sensor NEFD and other performance measures, false target irradiance levels at the sensor, and detection threshold. This probability can be expressed in concise terms showing dependence on parameters from the target, the optical path and the sensor.

P_2 depends on the sensor instantaneous field-of-view, the total search angle, scan geometry and on the sensor relative motion. Models

topographical representations) indicating the distribution and mix of the different classes of background sources.

1.2.2.1 Develop appropriate algorithms and determine the probability of encountering these background sources as a function of scenario.

Specific items in the statement of work were addressed according to characteristics of available data tapes and supporting information. The available data, which are described in Section 3.0, were limited to relatively benign backgrounds for the infrared warning receiver. Additionally, the tapes were received only two months prior to the contract completion date. Thus limited analyses were accomplished, and the emphasis was shifted to demonstrating specific analysis methods which could be applied to background data impacting infrared warning receivers as it becomes available.

Section 2.0 gives a brief theoretical development describing the effects of various sensing parameters on a statistical model for background radiances. Section 4.0 describes the analysis algorithms used for showing radiance-area characteristics. Again, these do not represent all analyses which could be implemented; however, they do provide useful descriptors.

Section 5.0 gives examples of the data analysis results for the limited data that was available. And finally, Section 6.0 gives a summary and conclusions about the implemented analysis methods.

Complete software listings are given in the Appendix.

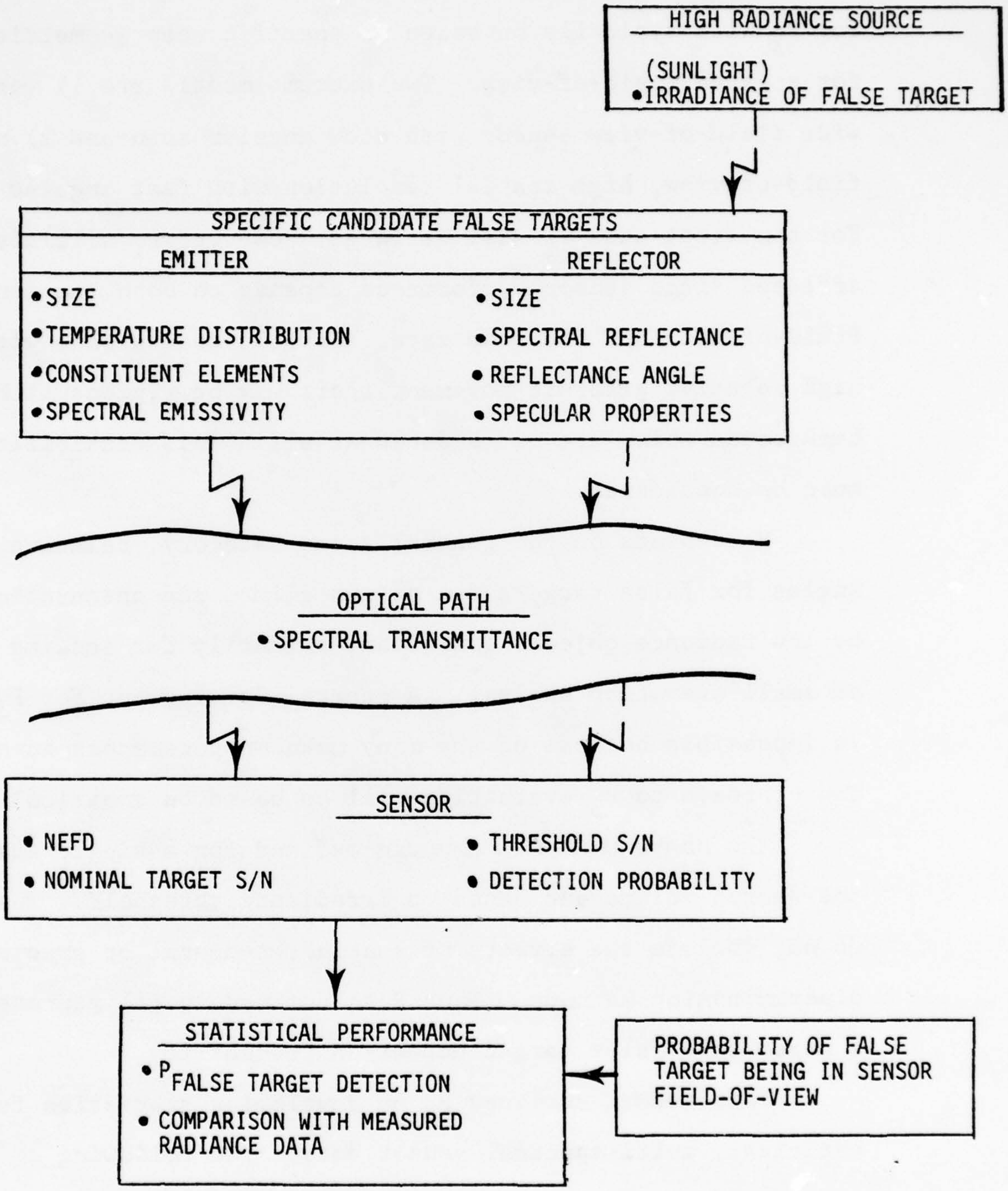


Figure 1. Modeling Features

for P_2 will typically be based on specific scan geometries for a given field-of-view. Two extreme models are 1) very wide field-of-view sensor with slow angular scan and 2) narrow field-of-view, high spatial resolution with fast angular scan. For the first case P_2 will be large; however, P_1 will also be affected since sensor performance depends on both the sensor field-of-view and the scan rate. For the second case with high relative aircraft movement there may be regions within the background which are not scanned at all. This possibility must be considered.

P_3 depends on the general scene category, relative sun angles for false targets due to sun glint, and obscuration by low radiance objects (important primarily for sensing at small elevation angles). A general development for P_3 is impossible because of the many unknown parameters involved. The approach to P_3 evaluation will be based on empirical data.

The above probabilities are defined for a single scan of the search volume and based on irradiance threshold. They do not include the effects of spatial, temporal or spectral discrimination methods. Thus P as defined in (1) represents a worst case false target detection probability.

This report examines P_3 by developing statistics for empirical, multi-spectral sensor data. The following sections describe the data, the statistics computed and results of statistical characterization of the data.

SECTION III. DESCRIPTION OF DATA TAPES TO BE ANALYZED

A single data tape containing nine files (scenes) of scanned, banded radiometric data in three spectral bands was provided by the Environmental Research Institute of Michigan (ERIM) for analysis as part of this contract. A description of that tape is paraphrased below from a memorandum provided with the tape.

A computer compatible data tape (CCT) was prepared that contains calibrated images from Point Mugu and Nellis AFB. Additional calibrated images will be prepared in the future but they have not been converted from high density digital tape (HDDT) to CCT at the present time. The calibration procedure is described in [1] and some statistics derived from the data on the tape are included in [2].

The nine track 1600 BPI data tape contains 9 files (images). The first two images are not good. Each file contains a title record followed by data records. Each data record contains one scan line of data. Data are put onto the tape with four 9-bit binary data values per (36-bit) word. Data values are limited in range from 0 to 255 for ease of processing on a 32-bit word machine. The first eight (36-bit) words in each data record are header information for the scan line. The first (36-bit) word is a scan line counter. Multispectral data are channel interleaved i.e., pixel 1 channel 1, pixel 1 channel 2, pixel 1 channel 3, . . . pixel 646 channel N.

The CCT was converted to 32-bit format at Auburn for ease of reading on the IBM370. The conversion was validated by comparing selected data values from the converted tape with values provided by ERIM.

The data values all fall in the range 0 to 255. To convert these digital numbers to radiances ($\mu W/cm^2 \cdot sr \cdot \mu m$ for the 2.0-2.6 μm channel or apparent temperatures (K for the 3.0-4.2, 3.5-3.9, 3.9-4.7, 4.5-5.5, 5.1-5.7, 9.0-11.4 μm channel), they have to be scaled as follows:

$$\text{Calibrated Data} = (\text{digital number})*MF + AF$$

The images, number of channels, spectral bands in order as they are on the tapes, number of scan lines, number of pixels per scan line, and MF and AF for each channel are given below.

File 3, NEVA1, channels 2.0-2.6, 3.0-4.2, 4.5-5.5, 5.1-5.7

271 records 646 pixels, 2584 bytes per record

	MF	AF	
2.0 - 2.6	3.0932	-14.9566	(approximate)
3.0 - 4.2	Bad Data		
4.5 - 5.5	.0316129	283.956	
5.1 - 5.7	.255415	261.200	(low SNR calibration very uncertain)

File 4, NEVA4, channels 3.9-4.7, 3.5-3.9, 9.0-11.4

215 records 646 pixels, 1938 bytes per record

	MF	AF
3.9 - 4.7	.178320	277.694
3.5 - 3.9	.626448	226.579
9.0 - 11.4	.0704379	284.457

File 5, NEVB, channels 3.9-4.7, 3.5-3.9, 5.1-5.7

899 records 646 pixels, 1938 bytes per record

	MF	AF
3.9 - 4.7	.085632	277.476
3.5 - 3.9	.484893	201.702
5.1 - 5.7	.517669	199.105

File 7, NEVC, channels 3.9-4.7, 3.5-3.9, 9.0-11.4

898 records 646 pixels, 1938 bytes per record

	MF	AF
3.9 - 4.7	.155668	276.012
3.5 - 3.9	.504799	224.004
9.0 - 11.4	.14172	279.92

File 8, NEVD, channels 3.9-4.7, 3.5-3.9, 9.0-11.4

1541 records 646 pixels, 1938 bytes per record

	MF	AF
3.9 - 4.7	.0966366	267.812
3.5 - 3.9	.469730	193.632
9.0 - 11.4	.127765	269.867

File 6, NEVE, channels 3.9-4.7, 3.5-3.9, 5.1-5.7

179 record, 646 pixels, 1938 bytes per record

	MF	AF
3.9 - 4.7	.127561	268.445
3.5 - 3.9	.644889	173.319
5.1 - 5.7	.537182	193.200

File 9, NEVF, channels 3.9-4.7, 3.5-3.9, 9.0-11.4

899 records 646 pixels, 1938 bytes per record

	MF	AF
3.9 - 4.7	.111736	270.111
3.5 - 3.9	.538573	193.809
9.0 - 11.4	.139151	273.470

All of the calibrated images have been processed to some degree. The angular resolution of the scanner is 2.5 mrad and the data are sampled every 2.5 mrad along the scan line. However, the scanner scans 60 lines/sec and the aircraft moves 202 ft/sec so that there is some scan line overlap in data collected for altitudes above 1350 ft. and in the data collected with the scanner tilted to look ahead of the aircraft in a 35° depression angle configuration. The processing that has been performed on the original data is one of line averaging yielding an along-track ground sample distance equal to the along track ground resolution. The effective ground resolution and ground sample distance for each image is given in the table on the following page.

There are five effects in the imagery and in the data that should be noted in any further processing of the data. (1) NEVA1 and NEVA4 are not continuous images. From an entire flight of several miles and 7000 scan lines, about 450 of every 500 were dropped in order to reduce the amount of data to be precessed. Note these imagery were collected to determine the magnitude of the sunglint and such sampling is adequate with the aircraft making a slow level turn normal to the suns azimuth; (2) Some of the data were obtained with a linear array of 2 or 3 detectors. Hence, the

data on the tape are not in spatial registration. This should be corrected for if correlations are to be measured. To bring the data into registration you have to shift the data as follows:

NEVA1	3.0-4.2	Shift Left	2 Pixels
	4.5-5.5	Shift Right	2 Pixels

i.e., registered pixels are

$(\text{pix}\,i)_{2.0\text{-}2.6}$, $(\text{pix}\,i)_{5.1\text{-}5.7}$,

$(\text{pix}\ i+2)_{3.0\text{-}4.2}$, $(\text{pix}\ i-2)_{4.5\text{-}5.5}$

All Others	3.9-4.7	Shift Right	2 Pixels
	3.5-3.9	Shift Left	2 Pixels

i.e., registered pixels are

$(\text{pix}\,i)_{5.1\text{-}5.7 \text{ or } 9.0\text{-}11.4}$

$(\text{pix}\ i-2)_{3.9\text{-}4.7}$

$(\text{pix}\ i+2)_{3.5\text{-}3.9}$

Data Summary

	A/C Alt. Above Terrain (Ft)	Scanner Depression (Deg.)	Cross-Track At Nadir (Ft.)		Along-Track At Nadir (Ft.)	
			Res	GSD	Res	GSD
NEVA1	2000	90	5.0	5.0	5.0	5.0
NEVA4	2000	90	5.0	5.0	5.0	5.0
NEVB	1000	35	4.36	4.36	7.60	7.60
NEVC	1000	35	4.36	4.36	7.60	7.60
NEVD	1750	90	4.38	4.38	4.38	4.38
NEVE	5000	35	12.5	12.5	38.00	38.00
NEVF	1000	35	4.36	4.36	7.60	7.60

	Date	Time	Heading	Terrain Type
NEVA1	3-7-78	1130	SW-SE	Water
NEVA4	3-7-78	1156	SW-SE	Water
NEVB	2-25-78	1511	E	Mountains
NEVC	2-25-78	1056	W	Desert
NEVD	2-25-78	0914	W	Mountains
NEVE	2-25-78	1424	E	Mountains
NEVF	2-25-78	1034	E	Mountains

(3) Because of the scanning optics the image of the detector array on the ground rotates as the scan mirror rotates. Directly beneath the aircraft and for scan angles to ± 20 degrees the software implemented time delays in (2) above should bring the data into spatial registration

to within a half pixel. In order to achieve registration for the larger scan angles (to ± 45° degrees) one would have to shift pixels from different lines, but this is probably not a worthwhile exercise because the along track ground resolution begins to exceed the along-track ground sample distance along the scan line by a factor of $\sec^2\theta$. (4) In the tilted scanner data there is some vignetting by the aircraft skin at the edges of the scans. Finally, (5) NEVC is an image of desert terrain at Nellis and the image is actually composed of two discontinuous segments of a larger image.

---

[1] Beard, J., Maxwell, J. R. and Spellicy, R., Statistical Analysis of Terrain Background Measurements Data, ERIM Report No. 120500-12-F, Environmental Research Institute of Michigan, Ann Arbor, March 1977.

[2] Maxwell, J. Robert, "Statistical Analyses of Selected Terrain and Water Background Measurements Data," ERIM, Report No. 132300-1-F, July 1978.

SECTION IV. SOFTWARE DESCRIPTION FOR DATA ANALYSIS

Development of software for this contract has resulted in the writing of three main programs. These are Plotit, Area and Shade. Plotit calculates amplitude statistics and generates amplitude histograms in terms of radiance (W/M^2-SR). Area defines blocks of connected "picture" elements whose radiance level is above a threshold. It also generates a histogram of number of elements in a block vs. their relative occurrence. Shade generates a "picture" from the data sets by linking areas corresponding to data values greater than a threshold.

To understand Plotit we must first look at the subroutines it uses. These are Rad, Quint, and Lion. Rad first converts an integer data value between 0 and 255 to an equivalent blackbody temperature using the equation T = MF (Data Value) + AF where MF and AF are given. Then using the equivalent temperature, Rad numerically integrates Planck's equation over the spectral band to determine the radiance level equivalent to the input integer data value. Subroutine Quint does the inverse of Rad. It finds the nearest integer equivalent to a radiance level which is inputed to it. Subroutine Lion generates axis and labeling for the histogram. It then scales and plots the data presented to it in two 1-D arrays, X and Y. The main program of Plotit first calculates values for the two arrays to be used for the amplitude histogram. X(I) is equal to the radiance corresponding to the integer I-1. Y(I) is equal to the number of data elements equal to I-1 divided by the total number of data elements. For X(I) and Y(I) I ranges from 1 to 256. The main program then calls Lion. From the arrays X(I) and Y(I) the main program next calculates unbiased

and consistent estimates for the mean (μ), variance (σ^2), and standard deviation (σ) by use of the equations below.

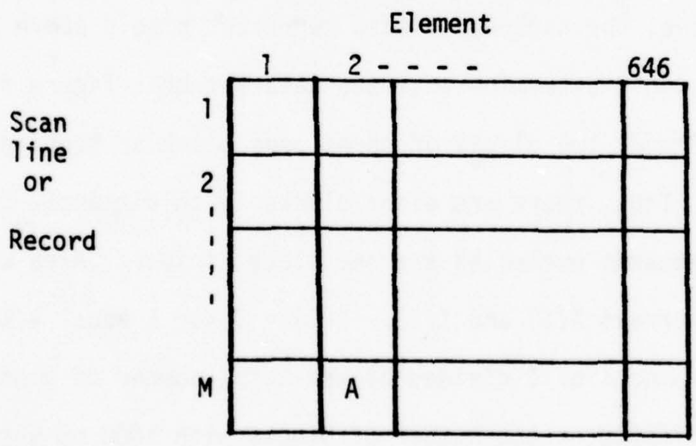
$$\hat{\mu} = \sum_{I=1}^{256} X(I)\ Y(I) \tag{9}$$

$$\hat{\sigma}^2 = \frac{N}{N-1}\ [(\sum_{I=1}^{256} [X(I)]^2\ \ Y(I)) - \hat{\mu}^2] \tag{10}$$

$$\hat{\sigma} = \sqrt{\hat{\sigma}^2} \tag{11}$$

where N equals the total number of pixels in a given image. Finally <u>Plotit</u> prints out the integer quantization values equivalent to radiance levels of $\hat{\mu} + .25n\hat{\sigma}$ for n equal 0 to 16. These values are used as thresholds in programs <u>Area</u> and <u>Shade</u>.

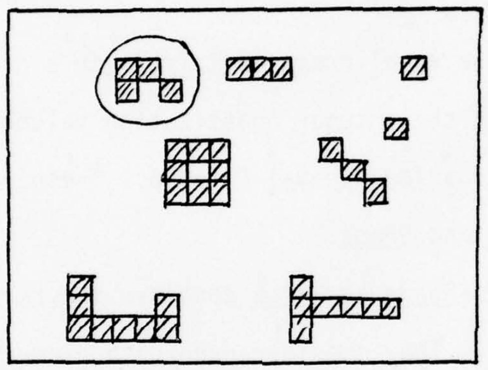
The programs <u>Shade</u> and <u>Area</u> consider the "scanned picture" nature of the data sets. They consider each data element as a square in a grid.



For example the second element of scan line M is the square labled A in the figure above.

The program Shade generates a 2-D plot by darkening squares corresponding to data points above a selectable threshold and leaving white all other blocks. The Program also draws a rectangle delimiting the bounds of the grid. To save CPU time the program darkens continuous blocks along a scan line at the same time.

Program Area is the most complicated of the three programs. Its operation is best explained in terms of an example.



In the figure above, the darkened blocks represent pixels above a given threshold. Area would determine that the data set this figure represents has two blocks of one, two blocks of three, one block of four and three blocks of eight. Thus, there are eight blocks in this example data set. Notice that the squares encircled are one block of four. Area calculates the value of two arrays X(I) and Y(I). X(I) = I for I equal 1 to 1000. Y(I) = number of blocks of I divided by the total number of blocks for I equal 1 to 999. Y(1000) = the number of blocks with 1000 or more elements divided by the total number of blocks. Using these arrays, a histogram is generated with a subroutine similar to Lion in Plotit. It is plotted for I equal one to 200. Nonzero values of Y(I) for $201 \leq I \leq 1000$ are printed out for evaluation. The option to print all histogram values is available also.

The above criteria for plotting only the first 200 area histogram values and for lumping all areas above 1000 were based on results obtained from analyzing the data. In fact the area histograms are heavily biased toward areas of twenty or fewer pixels. The point is that these plot parameters can be adjusted to best show scene dependent area statistics.

The computer generated plots were produced on a Versatec electrostatic plotter, which when properly adjusted should have the capability of generating gray scale plots. Software for gray scale plots was generated and tested using ten shades of gray as one inch bars across the plotter width. Difficulty was encountered with the darkest gray levels. Additionally the gray scale plot was inefficient because of the required mechanism for addressing the Versatec.

This program was abandoned because of the above mentioned problems and because other methods for gray scale image production already exist.

SECTION V. RESULTS OF ANALYSIS

Results of the analysis consist of the following

5.1 Data Summary Printout - For each spectral band and data file, the following information is printed: MEAN, STANDARD DEVIATION, VARIANCE, NUMBER OF PIXELS, MINIMUM RADIANCE (Corresponding to bin number 0), MAXIMUM RADIANCE (Corresponding to bin number 255), and BIN NUMBERS for selected fractional standard deviations above the mean.

5.2 Area Histogram Printout - For each spectral band, file and threshold, the areas above 200 pixels in size are printed out along with a total count of discrete areas for the scene and spectral band.

5.3 Amplitude Histogram Plots - For each file and spectral band an amplitude histogram based on all pixels is computed and plotted. Conversion of the data to radiances is accomplished prior to histogram computation.

5.4 Shade Plots - For each file, spectral band and threshold, a two-dimensional plot is generated showing only those pixels above the threshold. The threshold is chosen as some fractional standard deviation above the mean. Example plots are included in this report. Because of the large shaded areas, these plots had to be reproduced photographically.

5.5 Area Histogram Plots - For each file, spectral band and threshold as generated in 5.4, a histogram of areas is computed and plotted. Examples included verify the bias toward small areas.

The following pages illustrate results of the various computations. Identifying information is given for each figure.

INFORMATION FOR INTERPRETING LABELS

FILE	SPECTRAL BAND NUMBER	WAVELENGTH (MICRONS)	NAME
5	1	3.9 - 4.7	NEVB
5	2	3.5 - 3.9	NEVB
5	3	5.1 - 5.7	NEVB
6	1	3.9 - 4.7	NEVE
6	2	3.5 - 3.9	NEVE
6	3	5.1 - 5.7	NEVE
7	1	3.9 - 4.7	NEVC
7	2	3.5 - 3.9	NEVC
7	3	9.0 -11.4	NEVC
8	1	3.9 - 4.7	NEVD
8	2	3.5 - 3.9	NEVD
8	3	9.0 -11.4	NEVD
9	1	3.9 - 4.7	NEVF
9	2	3.5 - 3.9	NEVF
9	3	9.0 -11.4	NEVF

DATA SUMMARY FILE 5

SPECTRAL BAND 1

Mean = 5.76×10^{-1} $W\ M^{-2}\ SR^{-1}$

Standard Deviation = 9.96×10^{-3} $W\ M^{-2}\ SR^{-1}$

Variance = 9.92×10^{-5} $W^2\ M^{-4}\ SR^{-2}$

Number of Pixels = 580108

Maximum Radiance = 5.96×10^{-1} $W\ M^{-2}\ SR^{-1}$

Minimum Radiance = 5.53×10^{-1} $W\ M^{-2}\ SR^{-1}$

SPECTRAL BAND 2

Mean = 5.28×10^{-2} $W\ M^{-2}\ SR^{-1}$

Standard Deviation = 1.36×10^{-3} $W\ M^{-2}\ SR^{-1}$

Variance = 1.85×10^{-6} $W^2\ M^{-4}\ SR^{-2}$

Number of Pixels = 580108

Maximum Radiance = 5.80×10^{-2} $W\ M^{-2}\ SR^{-1}$

Minimum Radiance = 3.60×10^{-2} $W\ M^{-2}\ SR^{-1}$

SPECTRAL BAND 3

Mean = 1.67 $W\ M^{-2}\ SR^{-1}$

Standard Deveiation = 2.24×10^{-2} $W\ M^{-2}\ SR^{-1}$

Variance = 5.01×10^{-4} $W^2\ M^{-4}\ SR^{-2}$

Number of Pixels = 580108

Maximum Radiance = 1.95 $W\ M^{-2}\ SR^{-1}$

Minimum Radiance = 1.17 $W\ M^{-2}\ SR^{-1}$

DATA SUMMARY   FILE 6

SPECTRAL BAND 1

Mean = 5.76×10^{-1} $W\ M^{-2}\ SR^{-1}$

Standard Deviation = 1.15×10^{-2} $W\ M^{-2}\ SR^{-1}$

Variance = 1.32×10^{-4} $W^2\ M^{-4}\ SR^{-2}$

Number of Pixels = 114988

Maximum Radiance = 6.00×10^{-1} $W\ M^{-2}\ SR^{-1}$

Minimum Radiance = 5.35×10^{-1} $W\ M^{-2}\ SR^{-1}$

SPECTRAL BAND 2

Mean = 5.43×10^{-2} $W\ M^{-2}\ SR^{-1}$

Standard Deviation = 1.58×10^{-3} $W\ M^{-2}\ SR^{-1}$

Variance = 2.50×10^{-6} $W^2\ M^{-4}\ SR^{-2}$

Number of Pixels = 114988

Maximum Radiance = 6.07×10^{-2} $W\ M^{-2}\ SR^{-1}$

Minimum Radiance = 3.09×10^{-2} $W\ M^{-2}\ SR^{-1}$

SPECTRAL BAND 3

Mean = 1.64 $W\ M^{-2}\ SR^{-1}$

Standard Deviation = 1.43×10^{-2} $W\ M^{-2}\ SR^{-1}$

Variance = 2.04×10^{-4} $W^2\ M^{-4}\ SR^{-2}$

Number of Pixels = 114488

Maximum Radiance = 1.95 $W\ M^{-2}\ SR^{-1}$

Minimum Radiance = 1.14 $W\ M^{-2}\ SR^{-1}$

DATA SUMMARY FILE 7

SPECTRAL BAND 1

Mean = 5.91×10^{-1} $W\ M^{-2}\ SR^{-1}$

Standard Deviation = 6.26×10^{-3} $W\ M^{-2}\ SR^{-1}$

Variance = 3.92×10^{-5} $W^2\ M^{-4}\ SR^{-2}$

Number of Pixels = 579362

Maximum Radiance = 6.29×10^{-1} $W\ M^{-2}\ SR^{-1}$

Minimum Radiance = 5.50×10^{-1} $W\ M^{-2}\ SR^{-1}$

SPECTRAL BAND 2

Mean = 5.51×10^{-2} $W\ M^{-2}\ SR^{-1}$

Standard Deviation = 1.22×10^{-3} $W\ M^{-2}\ SR^{-1}$

Variance = 1.48×10^{-6} $W^2\ M^{-4}\ SR^{-2}$

Number of Pixels = 579462

Maximum Radiance = 6.29×10^{-2} $W\ M^{-2}\ SR^{-1}$

Minimum Radiance = 3.99×10^{-2} $W\ M^{-2}\ SR^{-1}$

SPECTRAL BAND 3

Mean = 5.71×10^{-10} $W\ M^{-2}\ SR^{-1}$

Standard Deviation = 6.41×10^{-2} $W\ M^{-2}\ SR^{-1}$

Variance = 4.10×10^{-3} $W^2\ M^{-4}\ SR^{-2}$

Number of Pixels = 579462

Maximum Radiance = 6.08 $W\ M^{-2}\ SR^{-1}$

Minimum Radiance = 5.38 $W\ M^{-2}\ SR^{-1}$

DATA SUMMARY FILE 8

SPECTRAL BAND 1

Mean = 5.66×10^{-1} $W\ M^{-2}\ SR^{-1}$

Standard Deviation = 8.93×10^{-3} $W\ M^{-2}\ SR^{-1}$

Variance = 7.98×10^{-5} $W^{2}\ M^{-4}\ SR^{-2}$

Number of Pixels = 994840

Maximum Radiance = 5.83×10^{-1}

Minimum Radiance = 5.34×10^{-1}

SPECTRAL BAND 2

Mean = 5.21×10^{-2} $W\ M^{-2}\ SR^{-1}$

Standard Deviation = 1.72×10^{-3} $W\ M^{-2}\ SR^{-1}$

Variance = 2.47×10^{-6} $W^{2}\ M^{-4}\ SR^{-2}$

Number of Pixels = 994840

Maximum Radiance = 5.59×10^{-2} $W\ M^{-2}\ SR^{-1}$

Minimum Radiance = 3.45×10^{-2} $W\ M^{-2}\ SR^{-1}$

SPECTRAL BAND 3

Mean = 5.48 $W\ M^{-2}\ SR^{-1}$

Standard Deviation = 1.06×10^{-1} $W\ M^{-2}\ SR^{-1}$

Variance = 1.13×10^{-2} $W^{2}\ M^{-4}\ SR^{-2}$

Number of Pixels = 994840

Maximum Radiance = 5.81 $W\ M^{-2}\ SR^{-1}$

Minimum Radiance = 5.19 $W\ M^{-2}\ SR^{-1}$

DATA SUMMARY FILE 9

SPECTRAL BAND 1

Mean = 5.70×10^{-1} $W\ M^{-2}\ SR^{-1}$

Standard Deviation = 1.02×10^{-2} $W\ M^{-2}\ SR^{-1}$

Variance = 1.04×10^{-4} $W^2\ M^{-4}\ SR^{-2}$

Number of Pixels = 580108

Maximum Radiance = 5.95×10^{-1} $W\ M^{-2}\ SR^{-1}$

Minimum Radiance = 5.38×10^{-1} $W\ M^{-2}\ SR^{-1}$

SPECTRAL BAND 2

Mean = 5.27×10^{-2} $W\ M^{-2}\ SR^{-1}$

Standard Deviation = 1.63×10^{-3} $W\ M^{-2}\ SR^{-1}$

Variance = 2.67×10^{-6} $W^2\ M^{-4}\ SR^{-2}$

Number of Pixels = 580108

Maximum Radiance = 5.90×10^{-2} $W\ M^{-2}\ SR^{-1}$

Minimum Radiance = 3.45×10^{-2} $W\ M^{-2}\ SR^{-1}$

SPECTRAL BAND 3

Mean = 5.52 $W\ M^{-2}\ SR^{-1}$

Standard Deviation = 1.19×10^{-1} $W\ M^{-2}\ SR^{-1}$

Variance = 1.41×10^{-2} $W^2\ M^{-4}\ SR^{-2}$

Number of Pixels = 580108

Maximum Radiance = 5.95 $W\ M^{-2}\ SR^{-1}$

Minimum Radiance = 5.26 $W\ M^{-2}\ SR^{-1}$

SUMMARY OF DATA NOT PLOTTED ON AREA HISTOGRAMS

OF FILE 5, SPECTRAL BAND 1

THRESHOLD = $\hat{\mu} + \hat{\sigma}$

NUMBER OF PIXELS IN A BLOCK	RELATIVE OCCURRENCE X 10^{-3}
205	1.6
213	1.6
222	1.6
256	1.6
495	1.6
529	1.6
805	1.6
977	1.6
1000 or Greater	19.0

TOTAL NUMBER OF BLOCKS = 644

THRESHOLD = $\hat{\mu} + 1.5\hat{\sigma}$

NUMBER OF PIXELS IN A BLOCK	RELATIVE OCCURRENCE X 10^{-3}
206	1.3
210	1.3
238	1.3
253	1.3
313	1.3
393	1.3
435	1.3
441	1.3
565	1.3
661	1.3
1000 or Greater	15.0

TOTAL NUMBER OF BLOCKS = 786

THRESHOLD = $\hat{\mu} + 2\hat{\sigma}$

TOTAL NUMBER OF BLOCKS = 325

SUMMARY OF DATA NOT PLOTTED ON AREA HISTOGRAMS

OF FILE 5, SPECTRAL BAND 2

THRESHOLD = $\hat{\mu} + \hat{\sigma}$

NUMBER OF PIXELS IN A BLOCK	RELATIVE OCCURRENCE X 10^{-4}
213	2.5
281	2.5
336	2.5
354	2.5
397	2.5
486	2.5
565	2.5
874	2.5
1000 or Greater	32.0

TOTAL NUMBER OF BLOCKS = 4070

THRESHOLD = $\hat{\mu} + 1.5\hat{\sigma}$

NUMBER OF PIXELS IN A BLOCK	RELATIVE OCCURRENCE X 10^{-4}
206	2.9
242	2.9
334	2.9
872	2.9
1000 or Greater	18.0

TOTAL NUMBER OF BLOCKS = 3404

THRESHOLD = $\hat{\mu} + 2\hat{\sigma}$

TOTAL NUMBER OF BLOCKS = 426

SUMMARY OF DATA NOT PLOTTED ON AREA HISTOGRAMS

OF FILE 5, SPECTRAL BAND 3

THRESHOLD = $\hat{\mu} + 1.5\hat{\sigma}$

NUMBER OF PIXELS IN A BLOCK	RELATIVE OCCURRENCE X 10^{-5}
288	7.2

TOTAL NUMBER OF BLOCKS = 13796

THRESHOLD = $\hat{\mu} + 2\hat{\sigma}$

TOTAL NUMBER OF BLOCKS = 6886

THRESHOLD = $\hat{\mu} + 2.5\hat{\sigma}$

TOTAL NUMBER OF BLOCKS = 1441

THRESHOLD = $\hat{\mu} + 3\hat{\sigma}$

TOTAL NUMBER OF BLOCKS = 161

SUMMARY OF DATA NOT PLOTTED ON AREA HISTOGRAM

OF FILE 7, SPECTRAL BAND 1

THRESHOLD = $\hat{\mu} + \hat{\sigma}$

NUMBER OF PIXELS IN A BLOCK	RELATIVE OCCURRENCE X 10^{-4}
209	3.5
216	3.5
213	3.5
217	3.5
231	3.5
235	3.5
244	3.5
253	3.5
266	3.5
284	3.5
297	3.5
306	3.5
326	3.5
347	3.5
354	3.5
364	3.5
438	3.5
443	3.5
454	3.5
477	3.5
590	3.5
604	3.5
712	3.5
904	3.5
934	3.5
961	3.5
962	3.5
1000 or Greater	28.0

TOTAL NUMBER OF BLOCKS = 2837

THRESHOLD = $\hat{\mu} + 1.5\hat{\sigma}$

NUMBER OF PIXELS IN A BLOCK	RELATIVE OCCURRENCE X 10^{-4}
225	9.7
437	9.7
567	9.7
863	9.7

TOTAL NUMBER OF BLOCKS = 1030

THRESHOLD = $\hat{\mu} + 2\hat{\sigma}$

TOTAL NUMBER OF BLOCKS = 14

SUMMARY OF DATA NOT PLOTTED ON AREA HISTOGRAMS

OF FILE 7, SPECTRAL BAND 2

THRESHOLD = $\hat{\mu} + \hat{\sigma}$

NUMBER OF PIXELS IN A BLOCK	RELATIVE OCCURRENCE X 10^{-4}
203	2.5
217	2.5
255	2.5
564	2.5
666	2.5
933	2.5
1000 or Greater	20.0

TOTAL NUMBER OF BLOCKS = 3950

THRESHOLD = $\hat{\mu} + 1.5\hat{\sigma}$

NUMBER OF PIXELS IN A BLOCK	RELATIVE OCCURRENCE X 10^{-4}
206	5.3
334	5.3
356	5.3
466	5.3
543	5.3
560	5.3
750	5.3
1000 or Greater	16.0

TOTAL NUMBER OF BLOCKS = 1893

THRESHOLD = $\hat{\mu} + 2\hat{\sigma}$

TOTAL NUMBER OF BLOCKS = 376

THRESHOLD = $\hat{\mu} + 2.5\hat{\sigma}$

TOTAL NUMBER OF BLOCKS = 2

SUMMARY OF DATA NOT PLOTTED ON AREA HISTOGRAMS

OF FILE 7, SPECTRAL BAND 3

THRESHOLD = $\hat{\mu} + \hat{\sigma}$

NUMBER OF PIXELS IN A BLOCK	RELATIVE OCCURRENCE X 10^{-4}
226	2.6
245	2.6
253	2.6
254	2.6
301	2.6
308	2.6
397	2.6
664	2.6
665	2.6
731	2.6
741	2.6
1000 or Greater	7.8

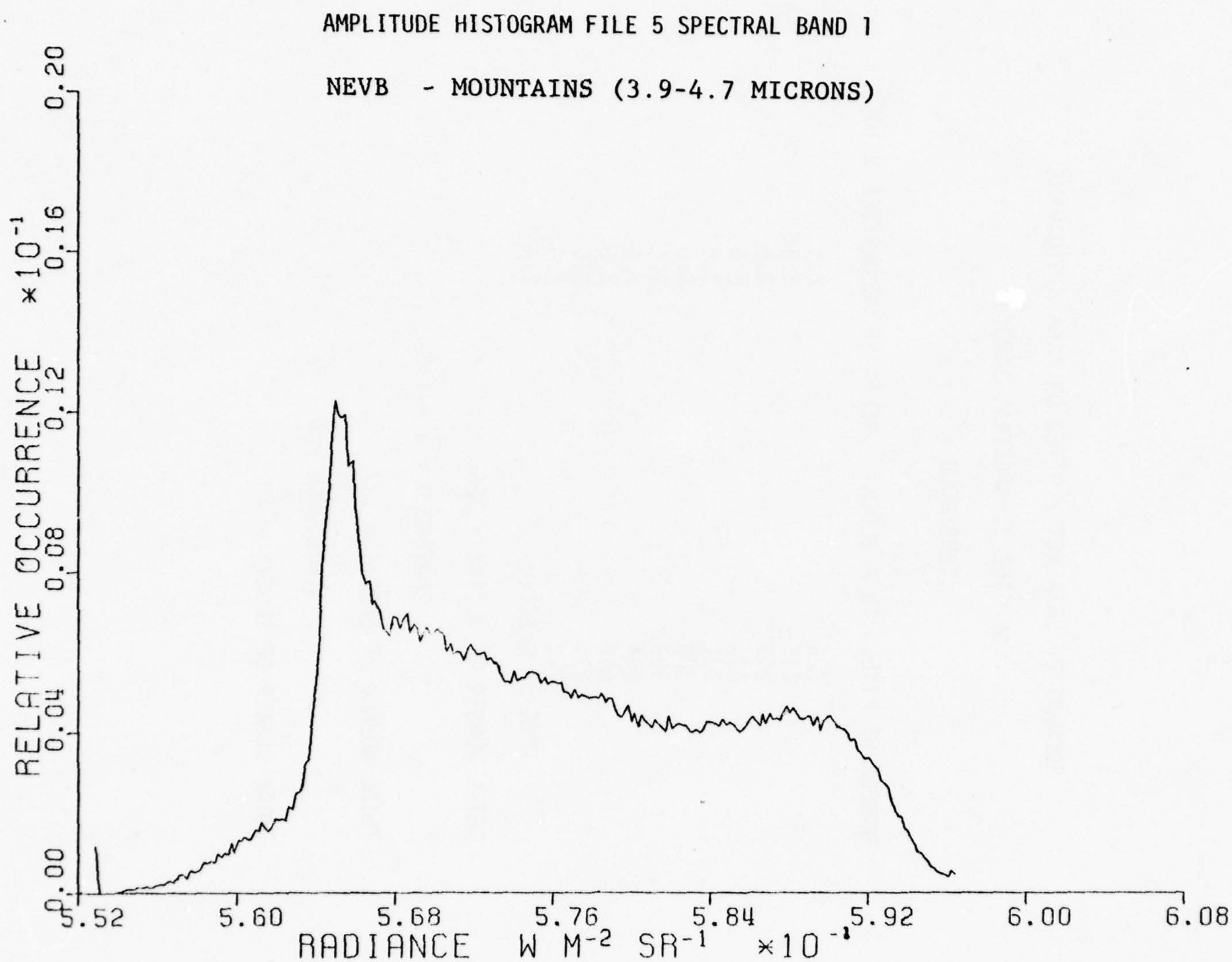
TOTAL NUMBER OF BLOCKS = 3858

THRESHOLD = $\hat{\mu} + 1.5\hat{\sigma}$

TOTAL NUMBER OF BLOCKS = 337

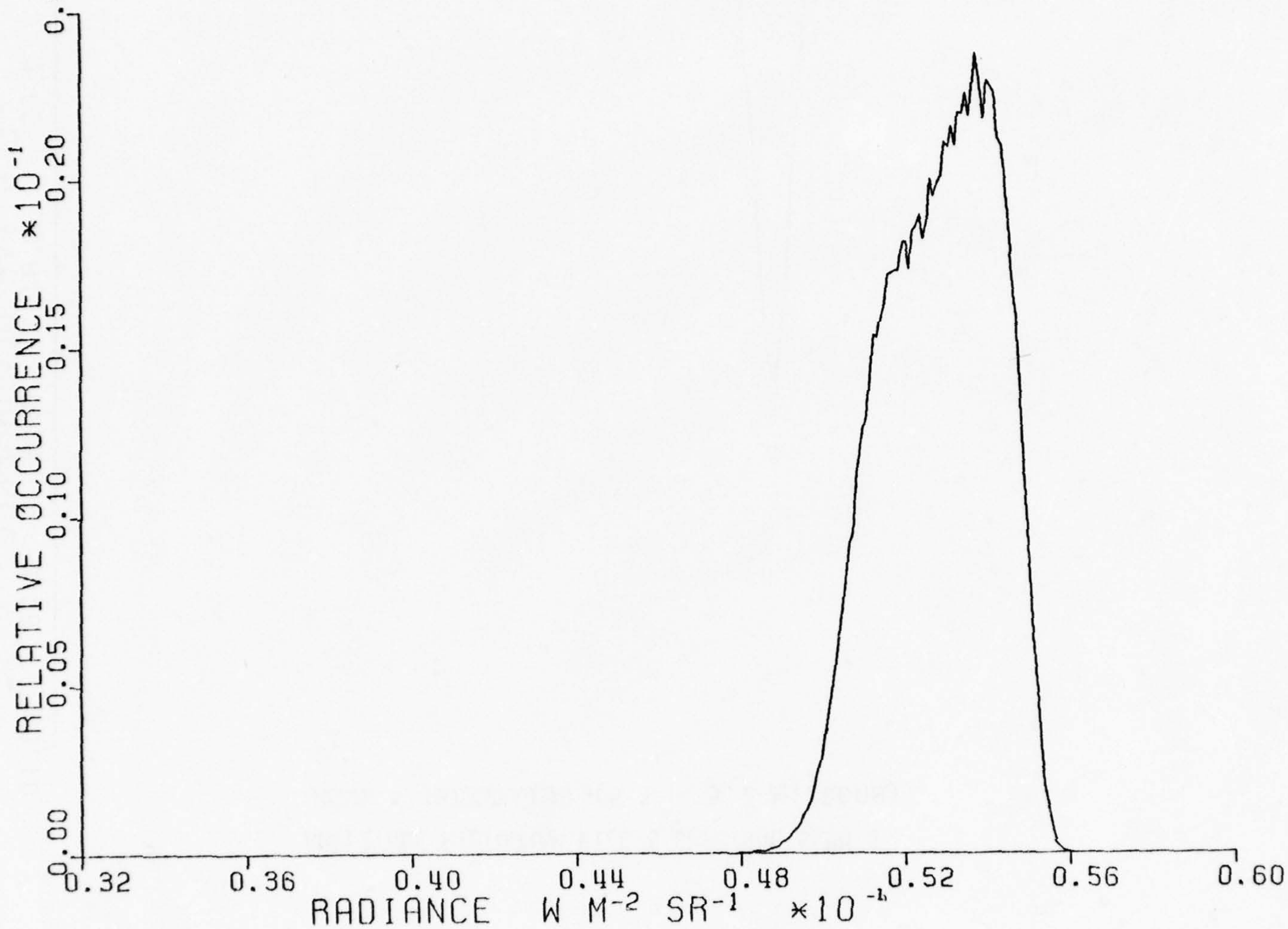
THRESHOLD = $\hat{\mu} + 2\hat{\sigma}$

TOTAL NUMBER OF BLOCKS = 4


AMPLITUDE HISTOGRAM FILE 5 SPECTRAL BAND 1
NEVB - MOUNTAINS (3.9-4.7 MICRONS)
RELATIVE OCCURRENCE *10⁻¹
0.00
0.04
0.08
0.12
0.16
0.20
5.52
5.60
5.68
5.76
5.84
5.92
6.00
6.08
RADIANCE W M⁻² SR⁻¹ *10⁻¹

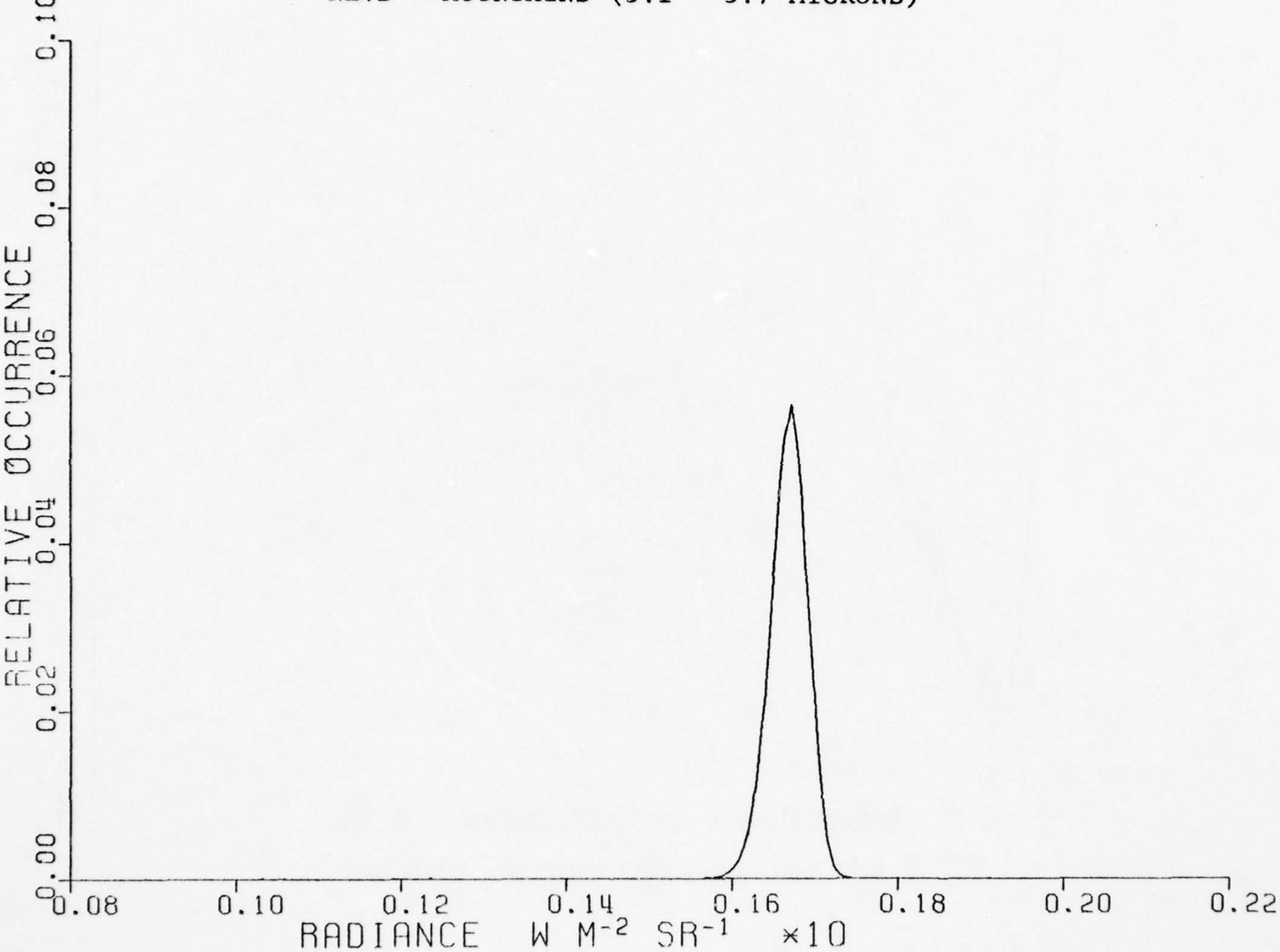
AMPLITUDE HISTOGRAM FILE 5 SPECTRAL BAND 2

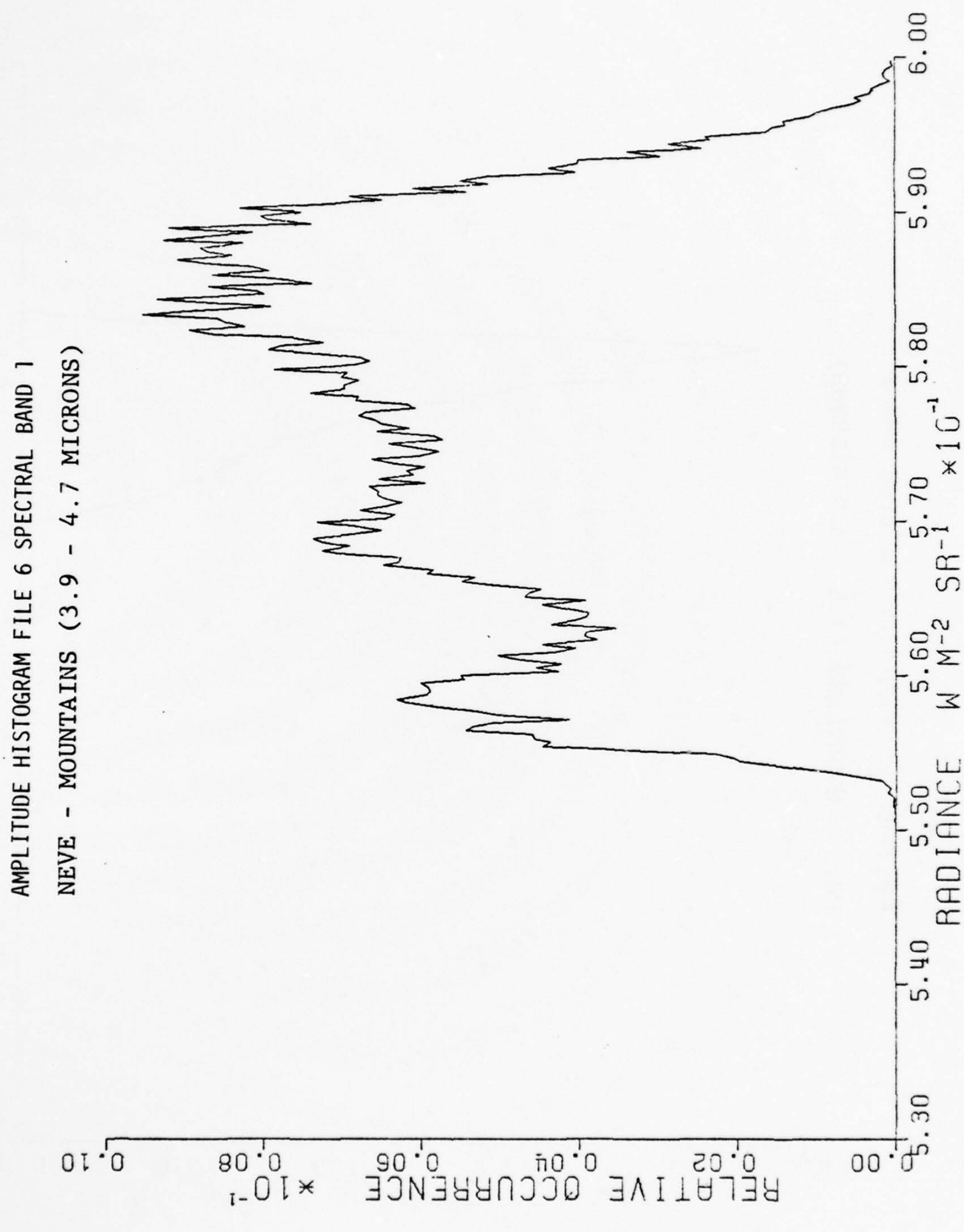
NEVB - MOUNTAINS (3.5-3.9 MICRONS)

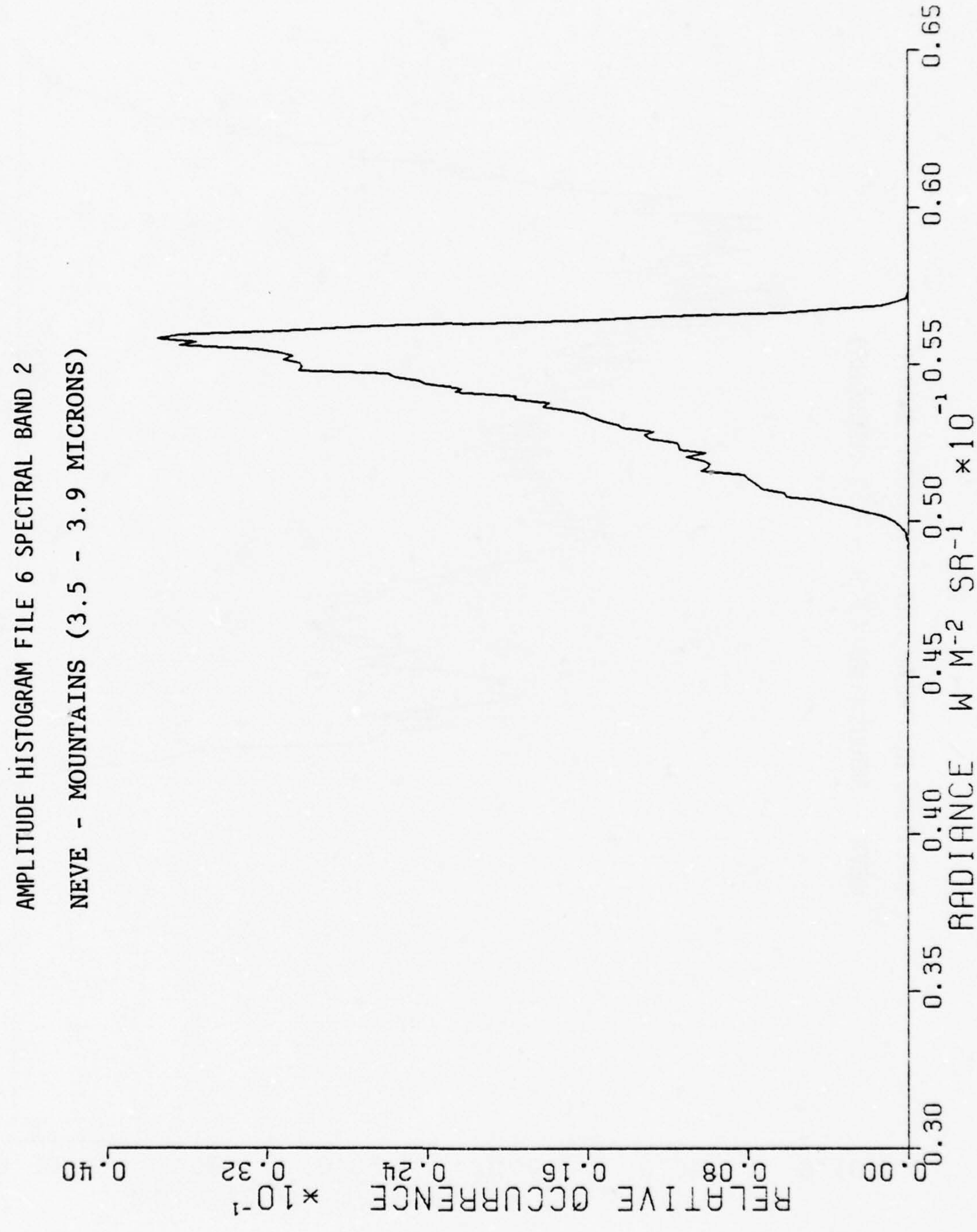


AMPLITUDE HISTOGRAM FILE 5 SPECTRAL BAND 3

NEVB - MOUNTAINS (5.1 - 5.7 MICRONS)

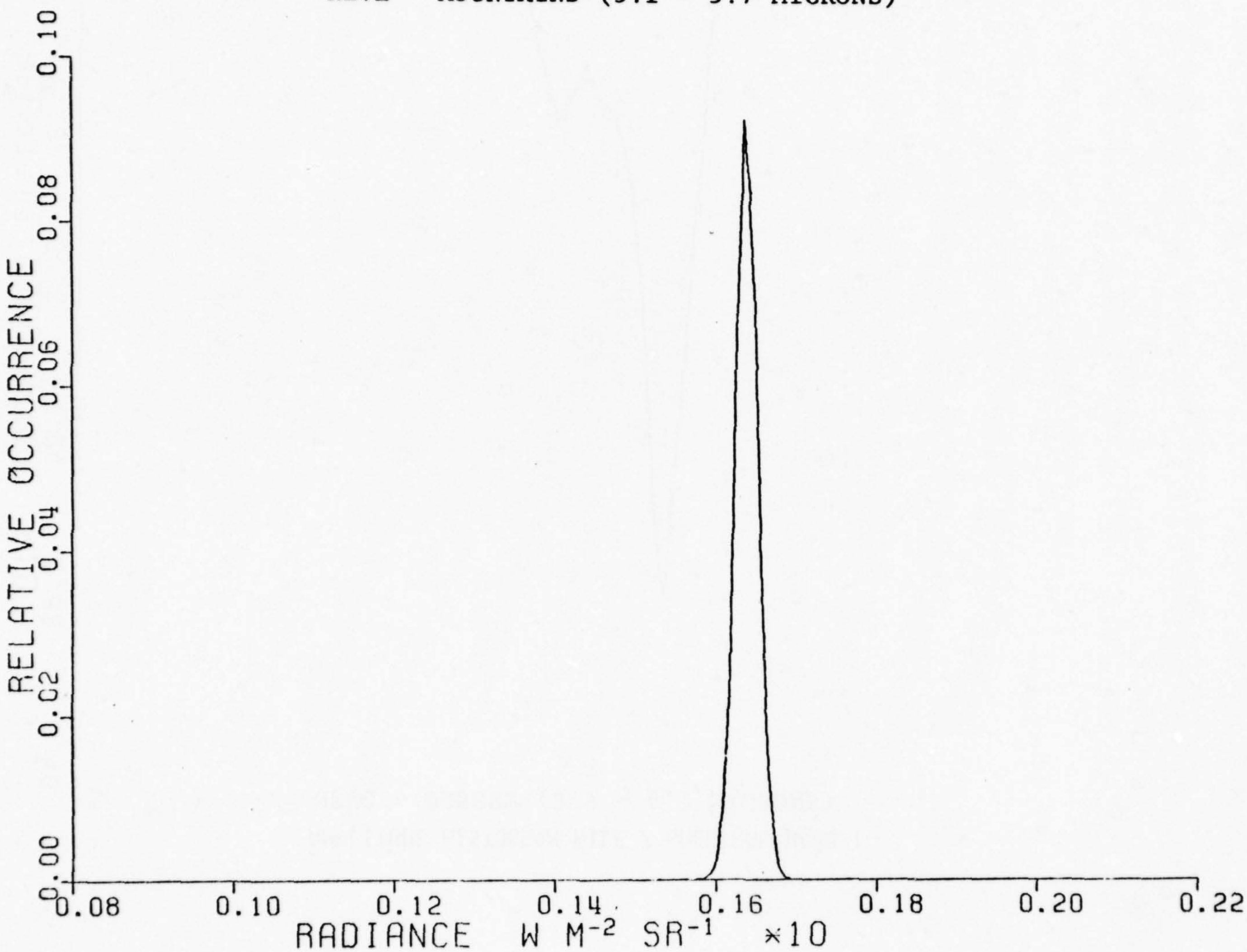


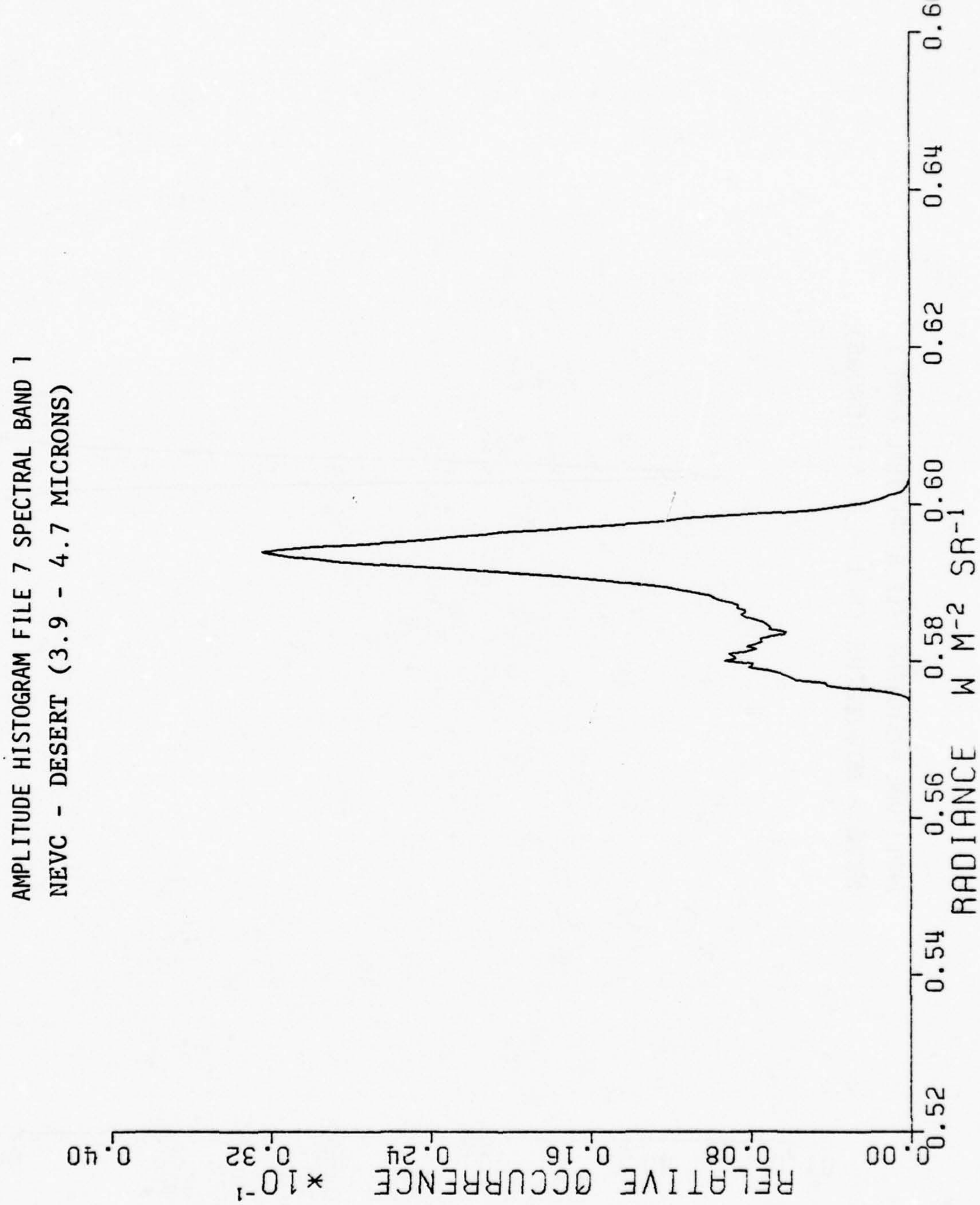

AMPLITUDE HISTOGRAM FILE 6 SPECTRAL BAND 1
NEVE - MOUNTAINS (3.9 - 4.7 MICRONS)
RELATIVE OCCURRENCE *10^-1
0.00
0.02
0.04
0.06
0.08
0.10
5.30
5.40
5.50
5.60
5.70
5.80
5.90
6.00
RADIANCE W M^-2 SR^-1 *10^-1


AMPLITUDE HISTOGRAM FILE 6 SPECTRAL BAND 2
NEVE - MOUNTAINS (3.5 - 3.9 MICRONS)
RELATIVE OCCURRENCE *10^{-1}
0.00
0.08
0.16
0.24
0.32
0.40
RADIANCE W M^{-2} SR^{-1} *10^{-1}
0.30
0.35
0.40
0.45
0.50
0.55
0.60
0.65

AMPLITUDE HISTOGRAM FILE 6 SPECTRAL BAND 3

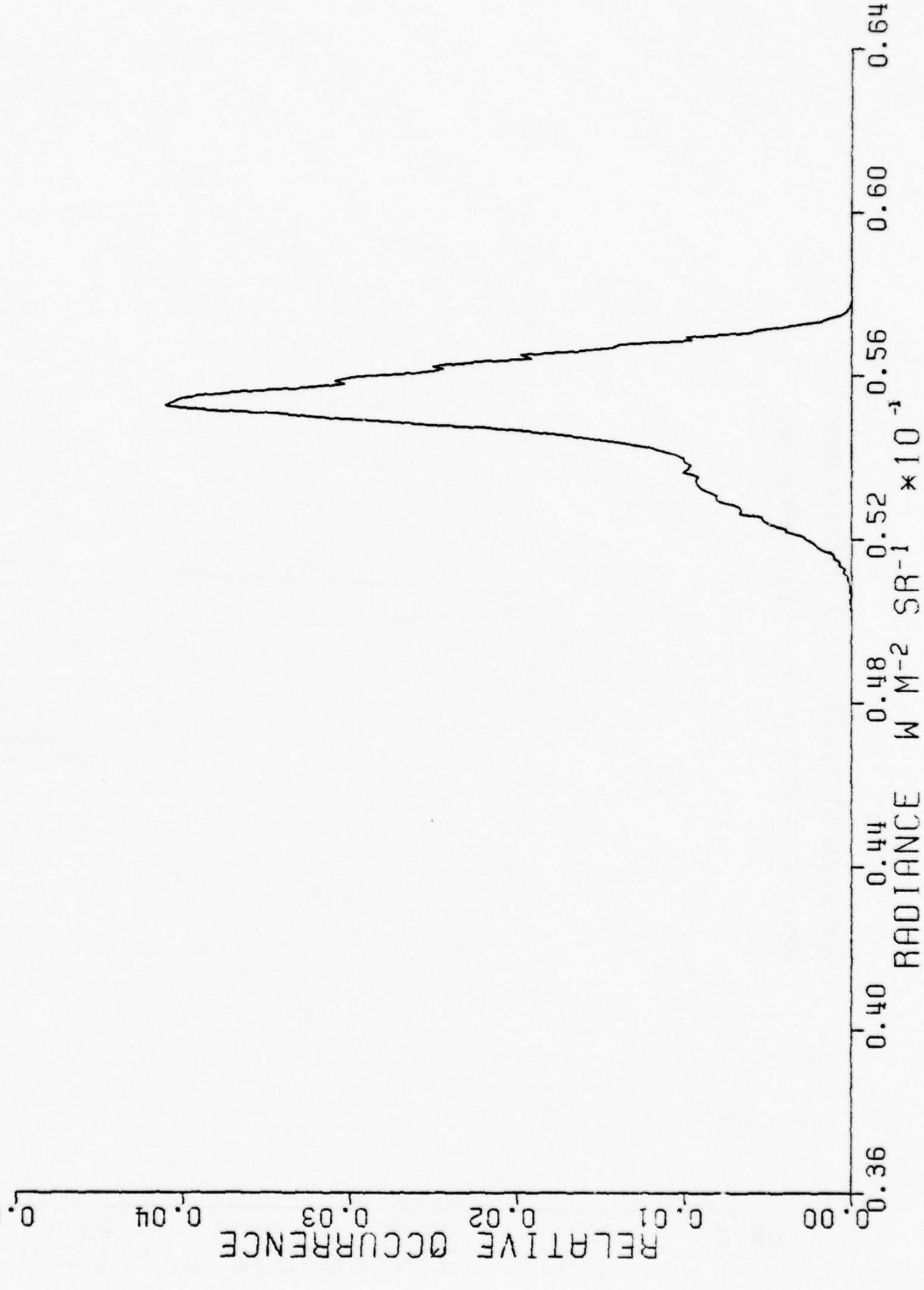
NEVE - MOUNTAINS (5.1 - 5.7 MICRONS)




AMPLITUDE HISTOGRAM FILE 7 SPECTRAL BAND 1
NEVC - DESERT (3.9 - 4.7 MICRONS)
RADIANCE W M-2 SR-1
RELATIVE OCCURRENCE *10-1
0.52
0.54
0.56
0.58
0.60
0.62
0.64
0.66
0.00
0.08
0.16
0.24
0.32
0.40

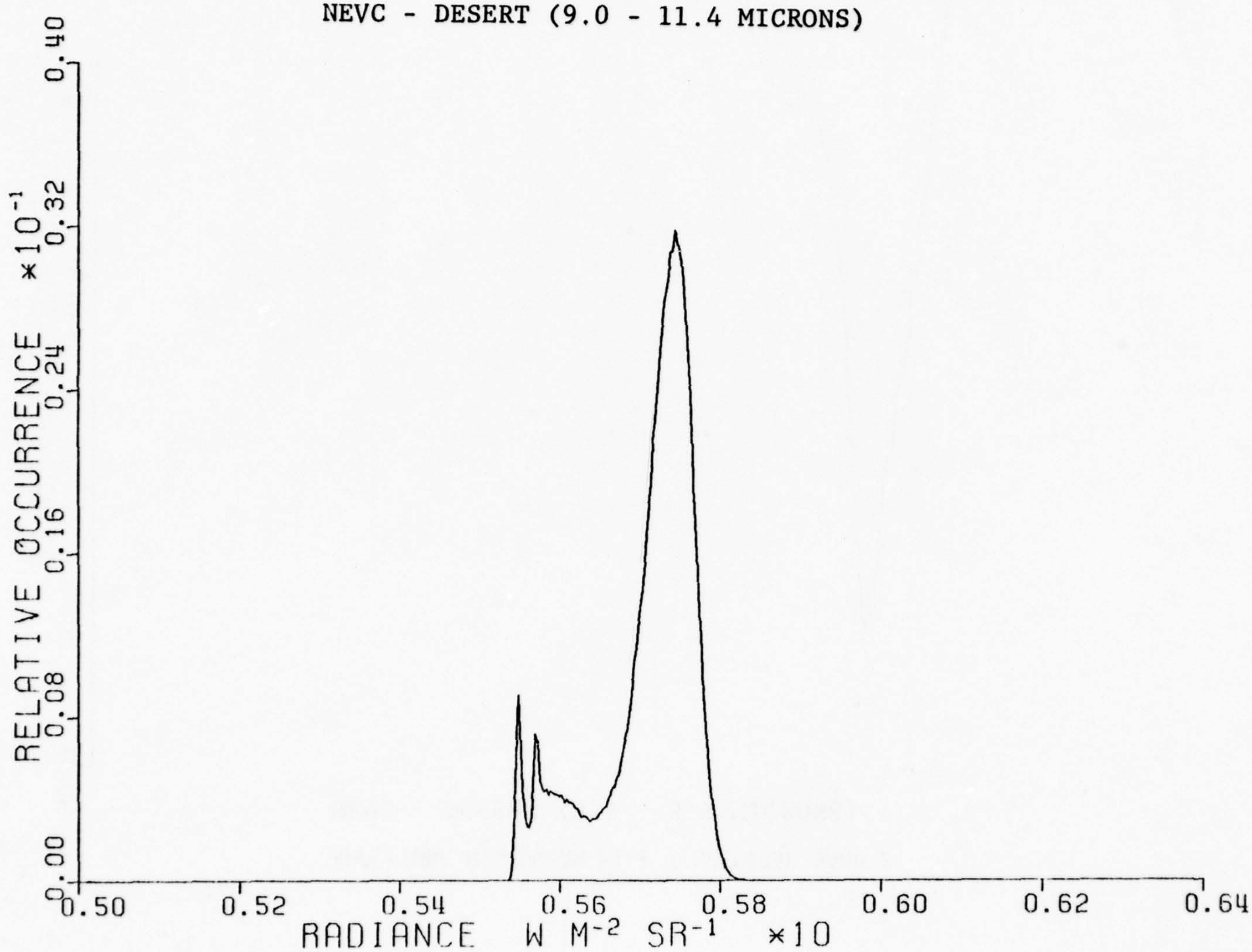
AMPLITUDE HISTOGRAM FILE 7 SPECTRAL BAND 2

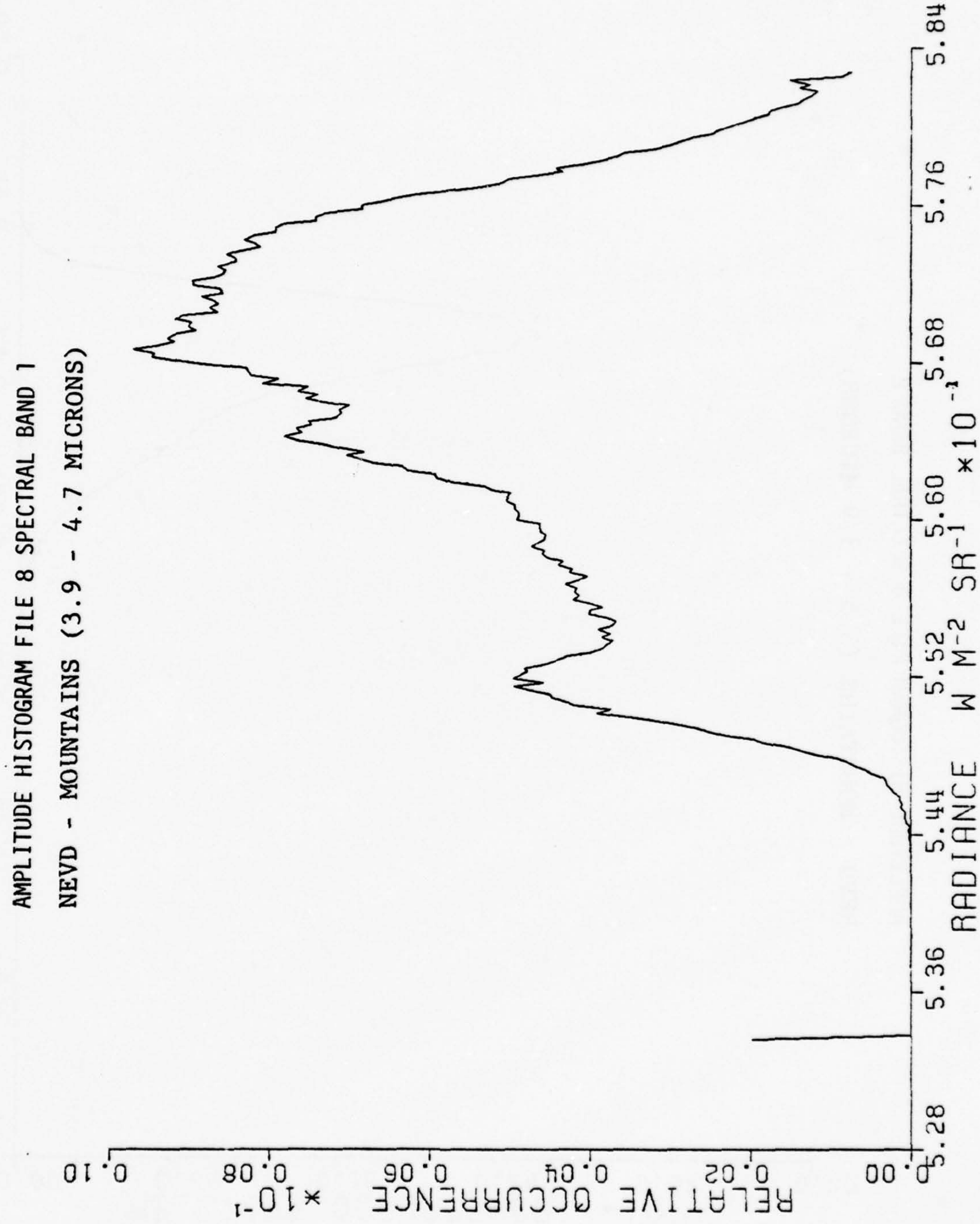
NEVC - DESERT (3.5 - 3.9 MICRONS)



AMPLITUDE HISTOGRAM FILE 7 SPECTRAL BAND 3

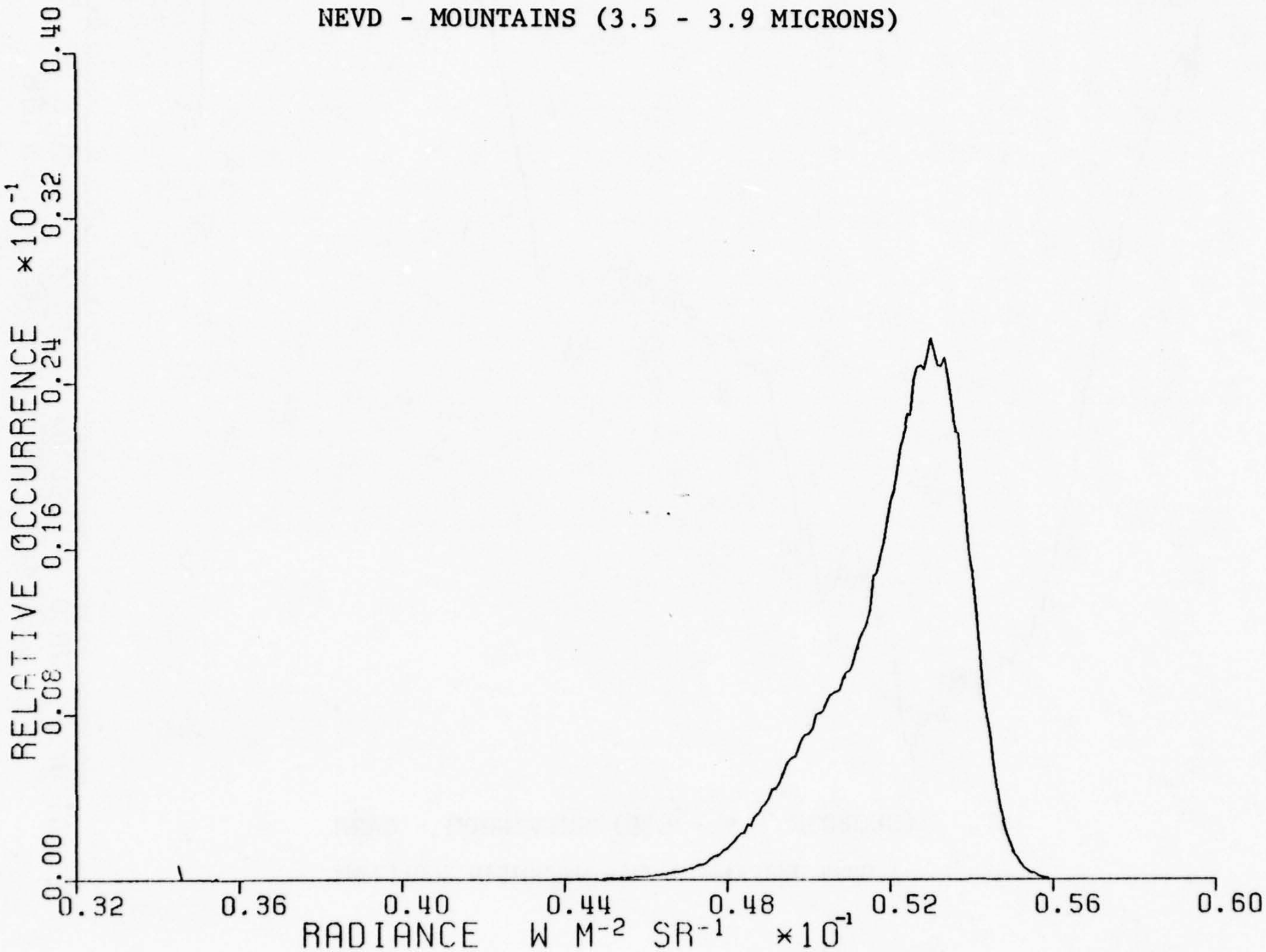
NEVC - DESERT (9.0 - 11.4 MICRONS)

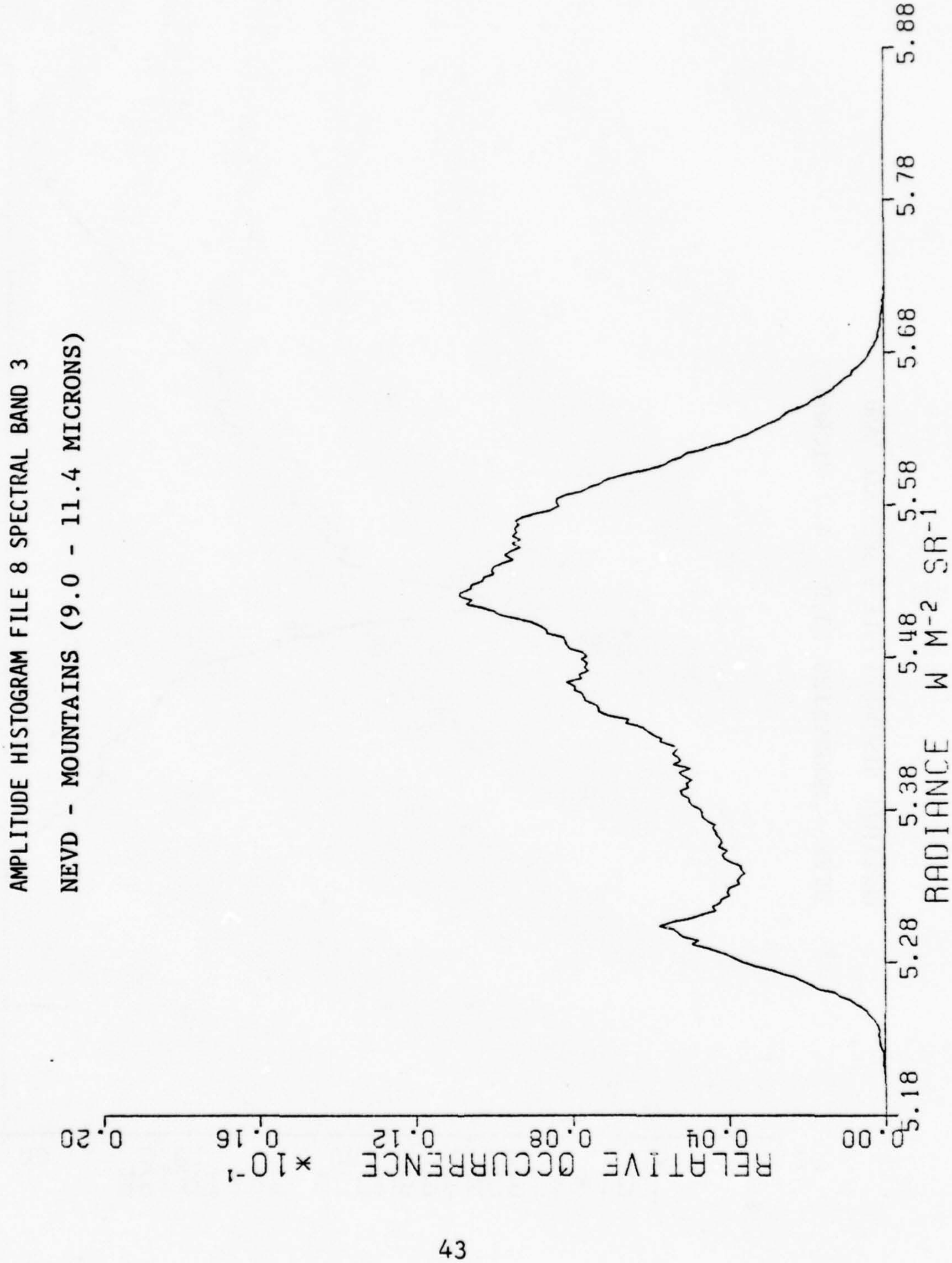



AMPLITUDE HISTOGRAM FILE 8 SPECTRAL BAND 1
NEVD - MOUNTAINS (3.9 - 4.7 MICRONS)
RADIANCE W M-2 SR-1 *10-1
5.28
5.36
5.44
5.52
5.60
5.68
5.76
5.84
RELATIVE OCCURRENCE *10-1
0.00
0.02
0.04
0.06
0.08
0.10

AMPLITUDE HISTOGRAM FILE 8 SPECTRAL BAND 2

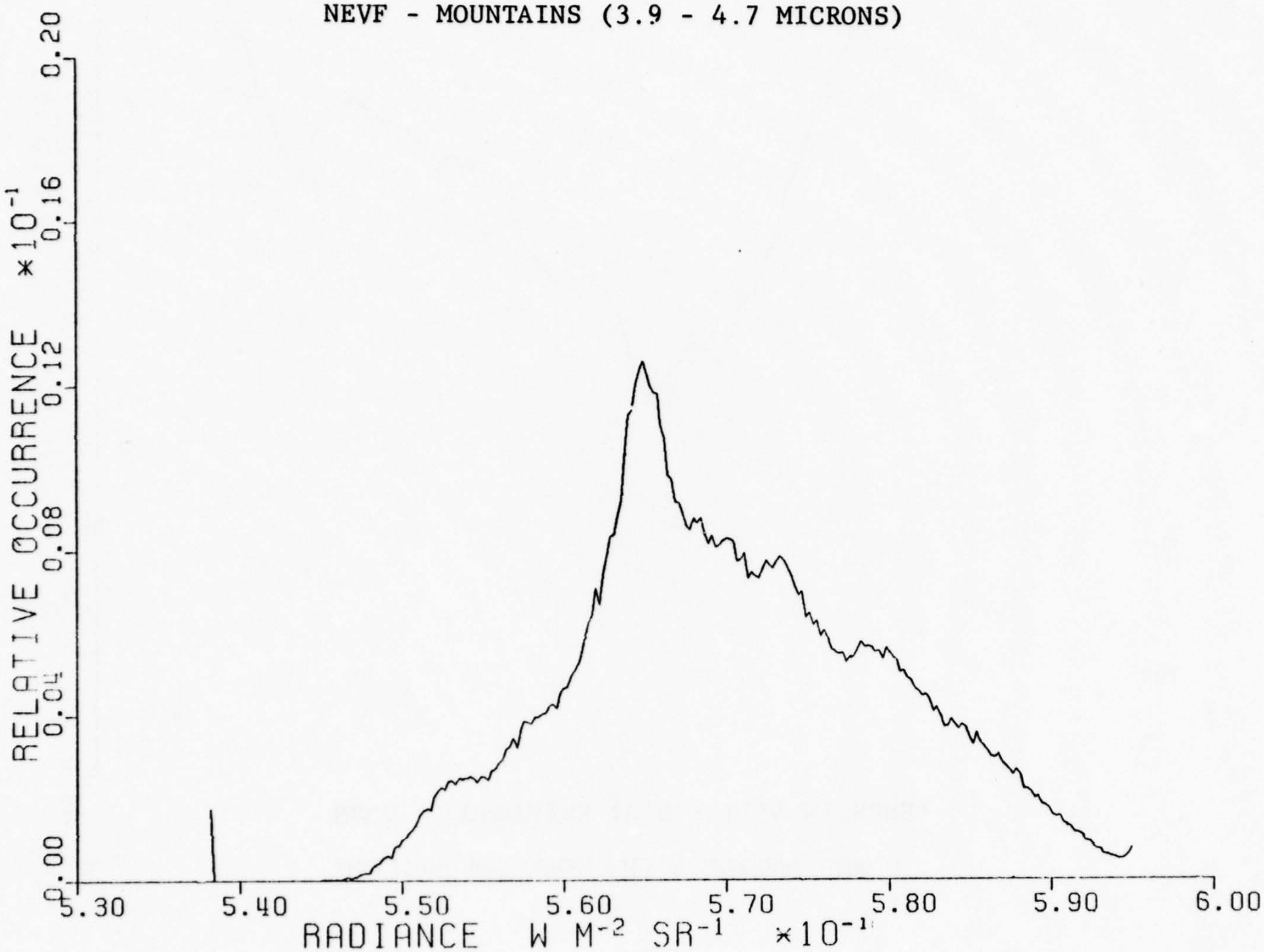
NEVD - MOUNTAINS (3.5 - 3.9 MICRONS)




AMPLITUDE HISTOGRAM FILE 8 SPECTRAL BAND 3
NEVD - MOUNTAINS (9.0 - 11.4 MICRONS)
RELATIVE OCCURRENCE $\times 10^{-1}$
0.00
0.04
0.08
0.12
0.16
0.20
RADIANCE W M^{-2} SR^{-1}
5.18
5.28
5.38
5.48
5.58
5.68
5.78
5.88

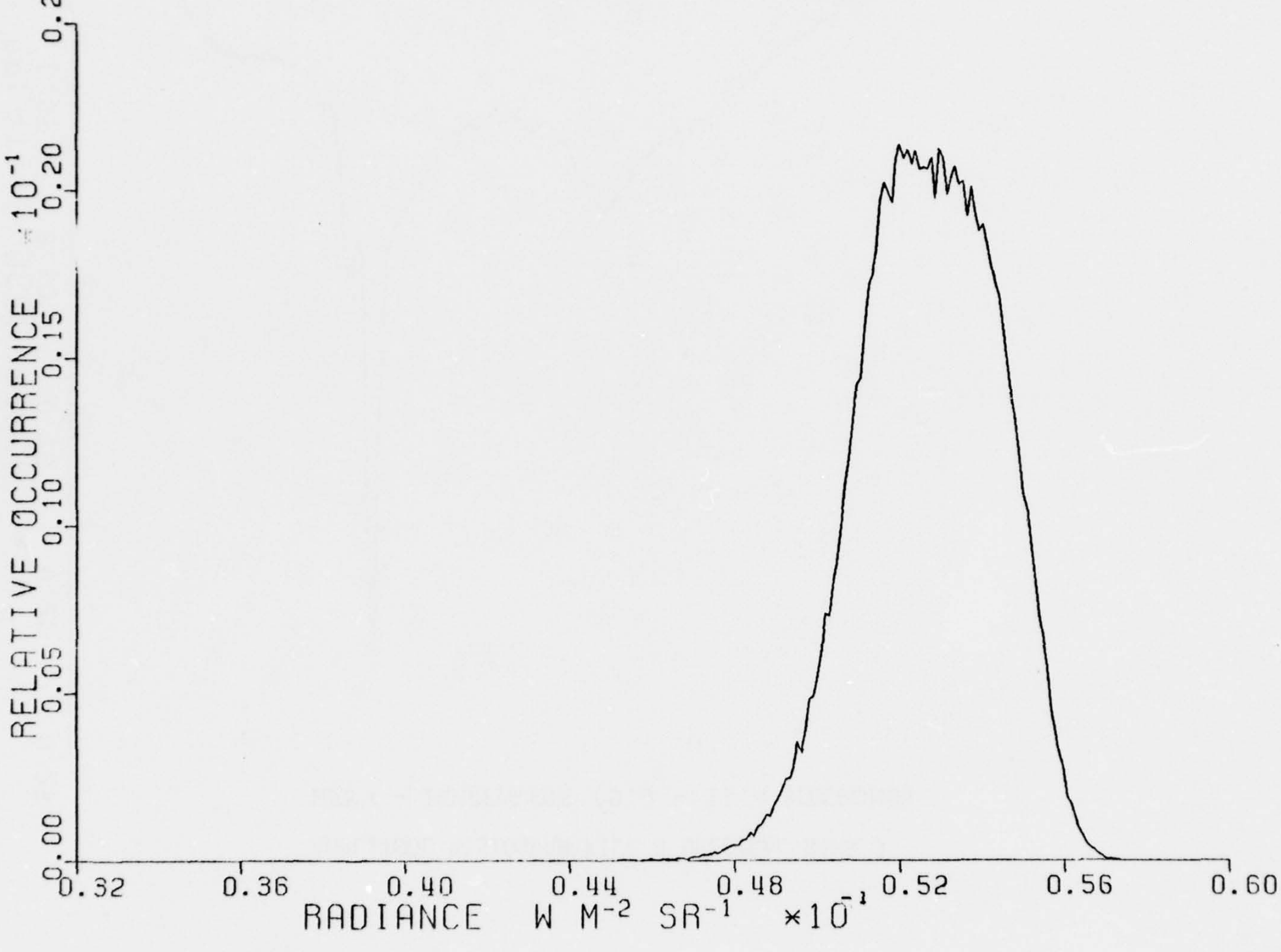
AMPLITUDE HISTOGRAM FILE 9 SPECTRAL BAND 1

NEVF - MOUNTAINS (3.9 - 4.7 MICRONS)



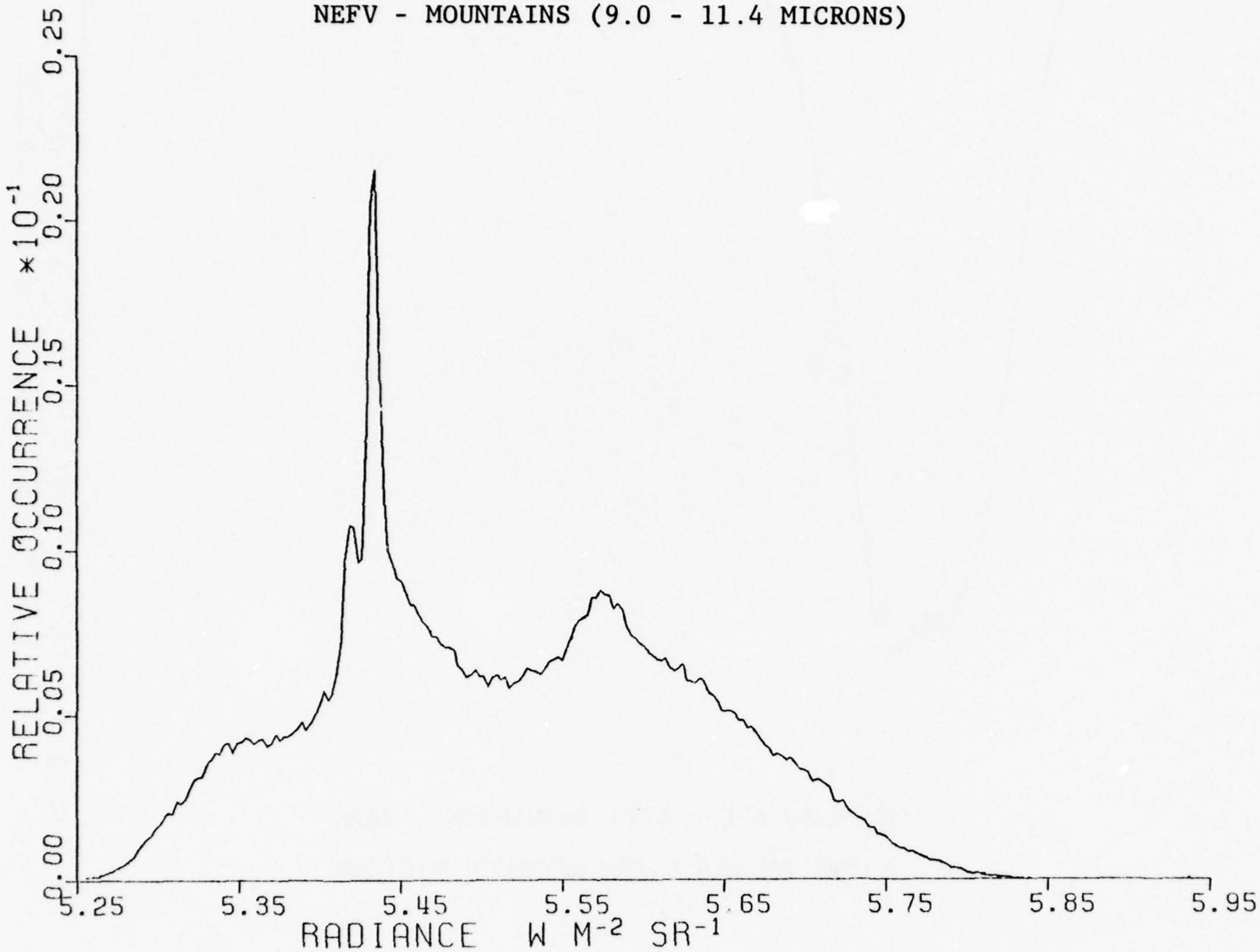
AMPLITUDE HISTOGRAM FILE 9 SPECTRAL BAND 2

NEVF - MOUNTAINS (3.5 - 3.9 MICRONS)



AMPLITUDE HISTOGRAM FILE 9 SPECTRAL BAND 3

NEFV - MOUNTAINS (9.0 - 11.4 MICRONS)



SHADE PLOT FILE 5 SPECTRAL BAND 1
THRESHOLD = $\hat{\mu} + \hat{\sigma}$
NEVB-MOUNTAINS (3.9-4.7 MICRONS)

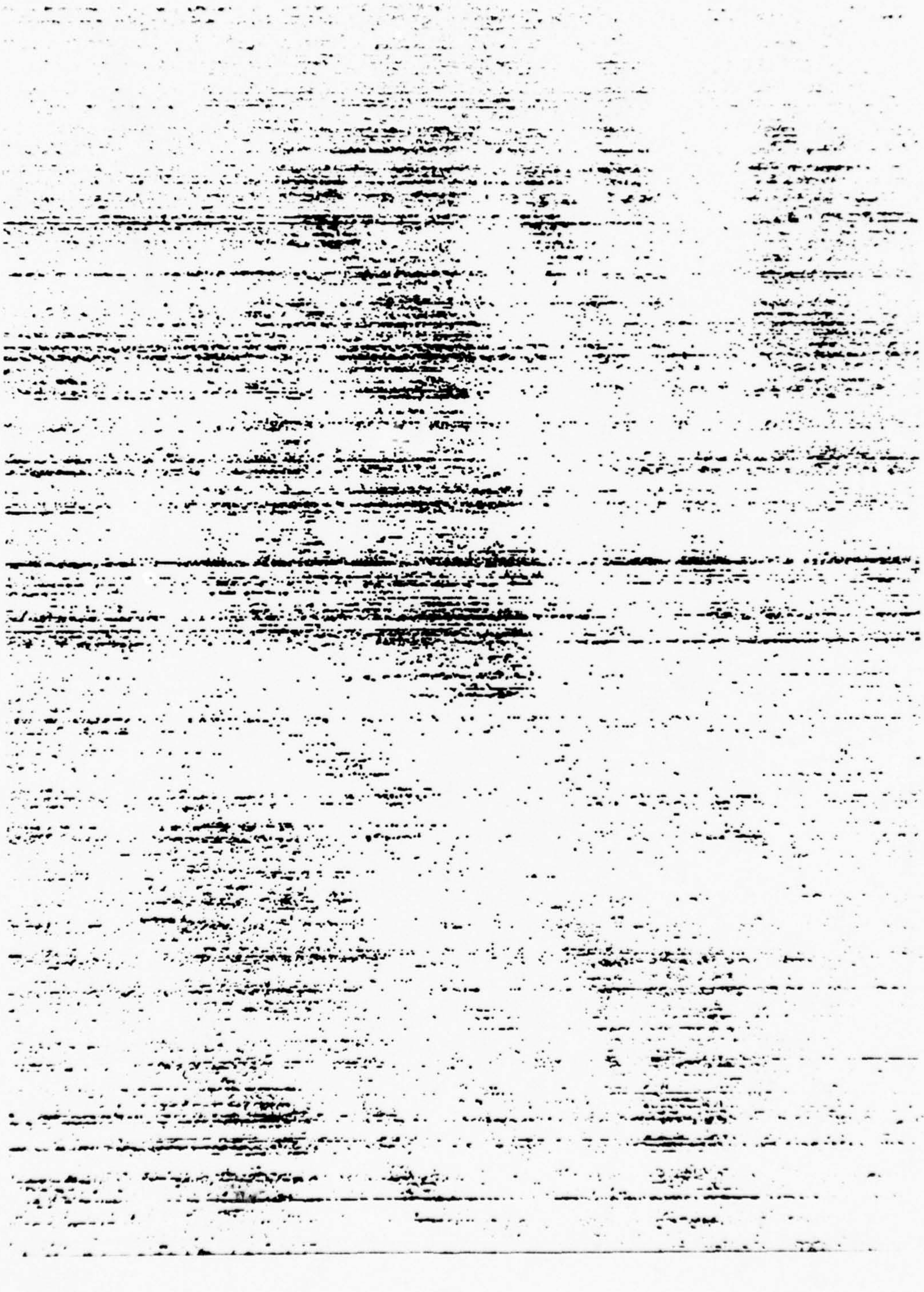
SHADE PLOT FILE 5 , SPECTRAL BAND 1
THRESHOLD = $\mu + 1.5\hat{\sigma}$
NEVB-MOUNTAINS (3.9-4.7 MICRONS)

SHADE PLOT FILE 5 SPECTRAL BAND 1
THRESHOLD = $\hat{\mu} + 2\hat{\sigma}$
NEVB-MOUNTAINS (3.9-4.7 MICRONS)

SHADE PLOT FILE 5 SPECTRAL BAND 2
THRESHOLD = $\hat{\mu} + 1.5\hat{\sigma}$
NEVB-MOUNTAINS (3.5-3.9 MICRONS)

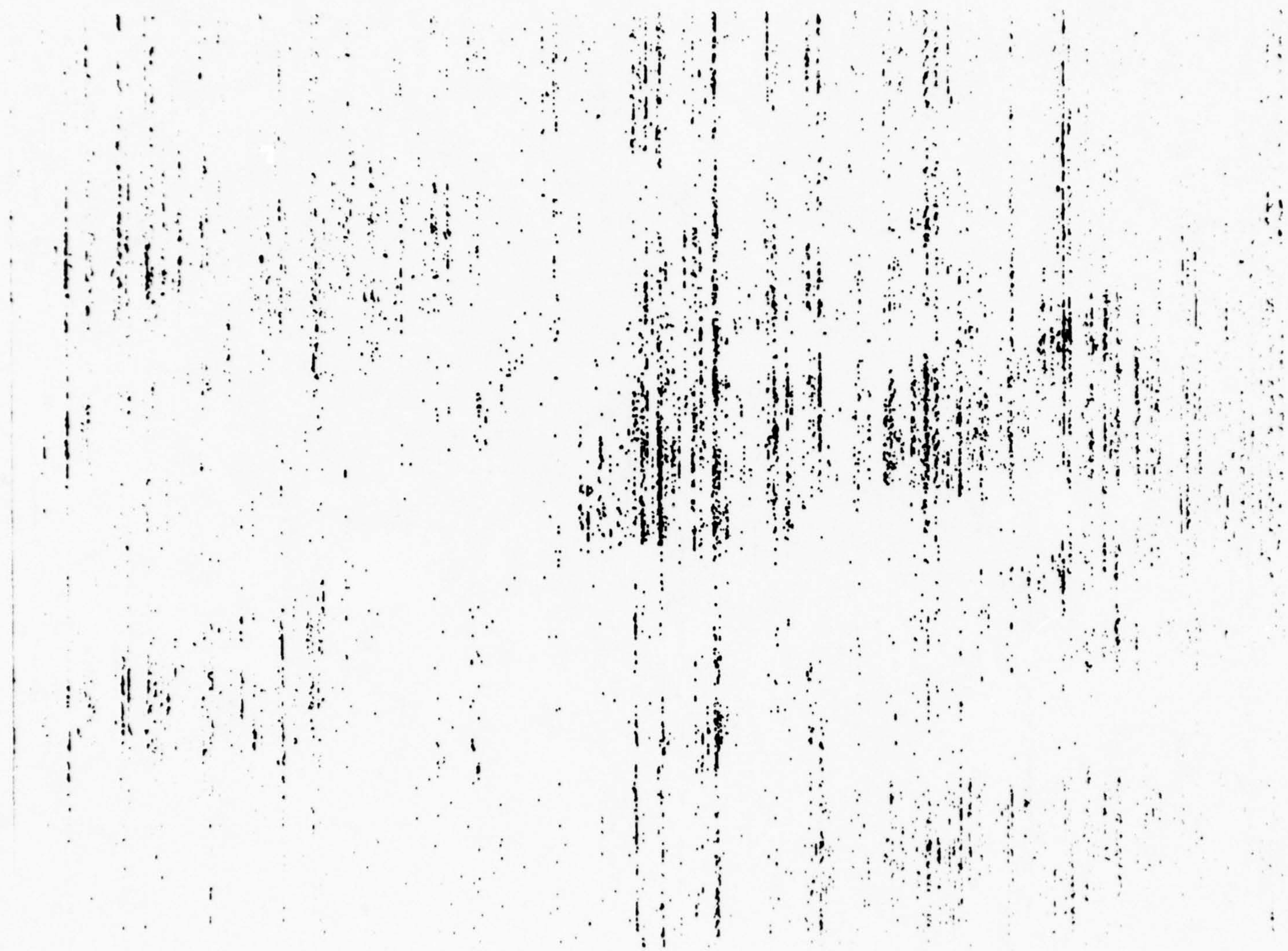
SHADE PLOT FILE 5 SPECTRAL BAND 2
THRESHOLD = $\hat{\mu} + 2\hat{\sigma}$

NEVB-MOUNTAINS (3.5-3.9 MICRONS)

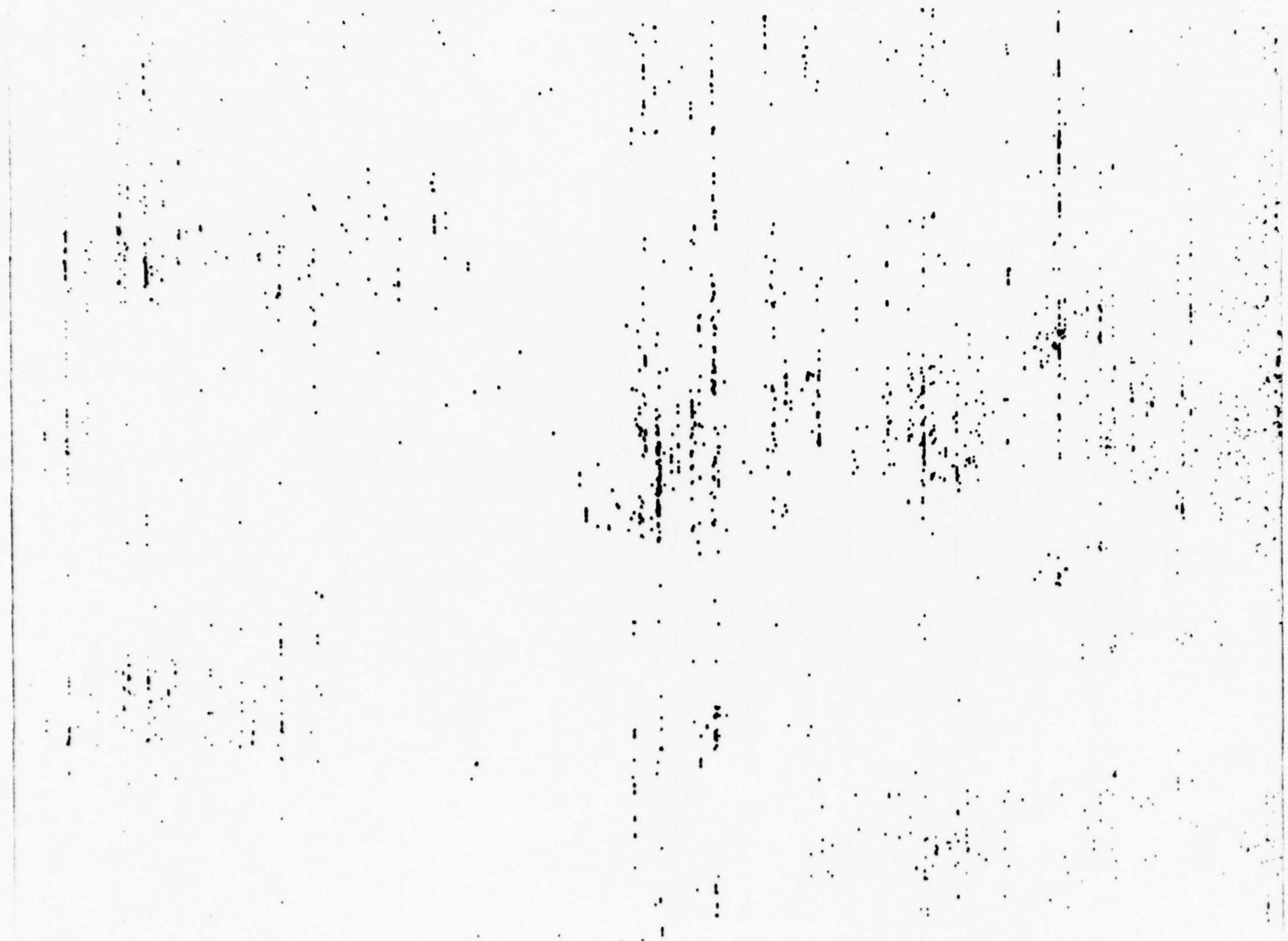


SHADE PLOT FILE 5 SPECTRAL BAND 3
THRESHOLD = $\hat{\mu} + 1.5\hat{\sigma}$

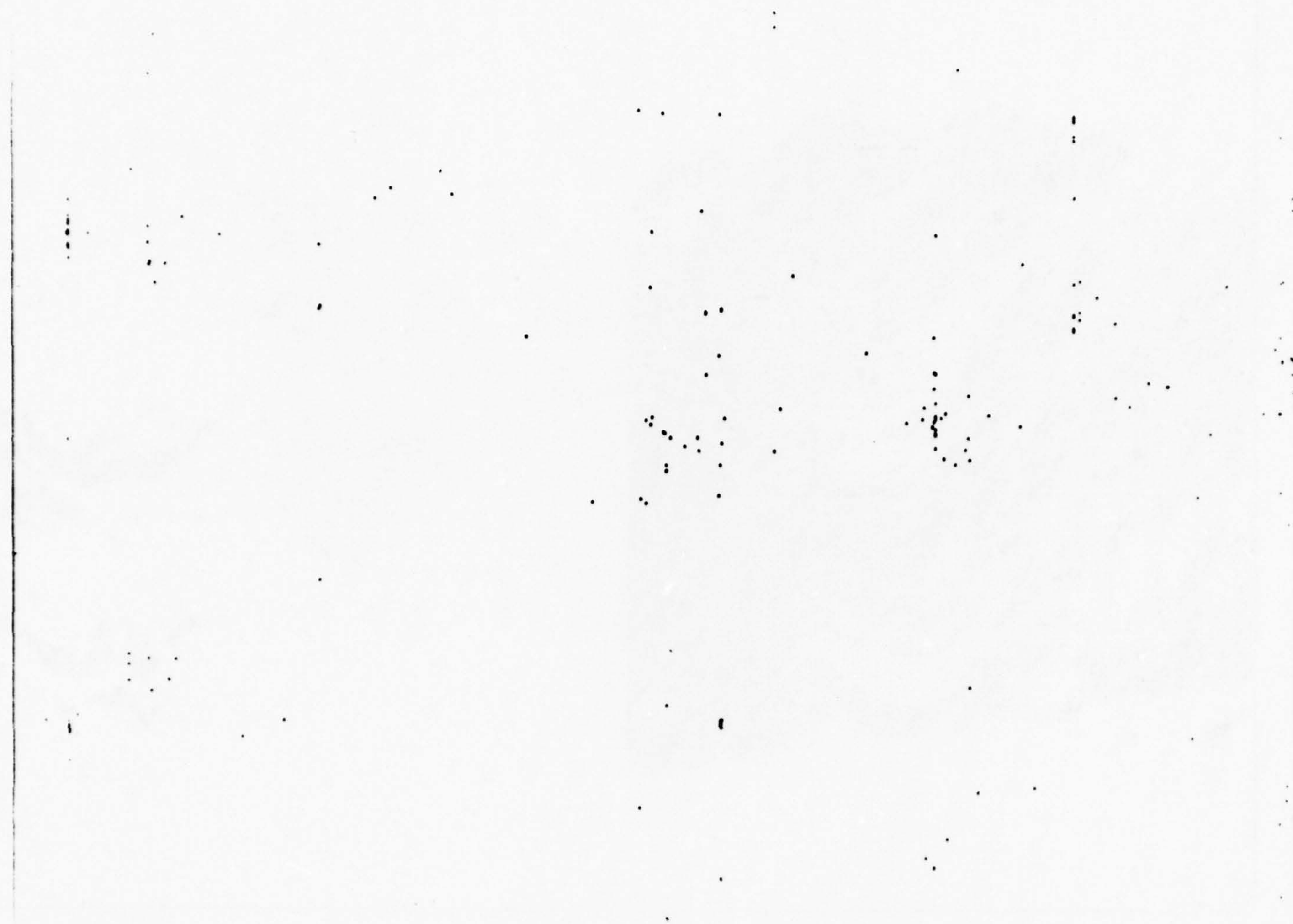
NEVB-MOUNTAINS (5.1-5.7 MICRONS)



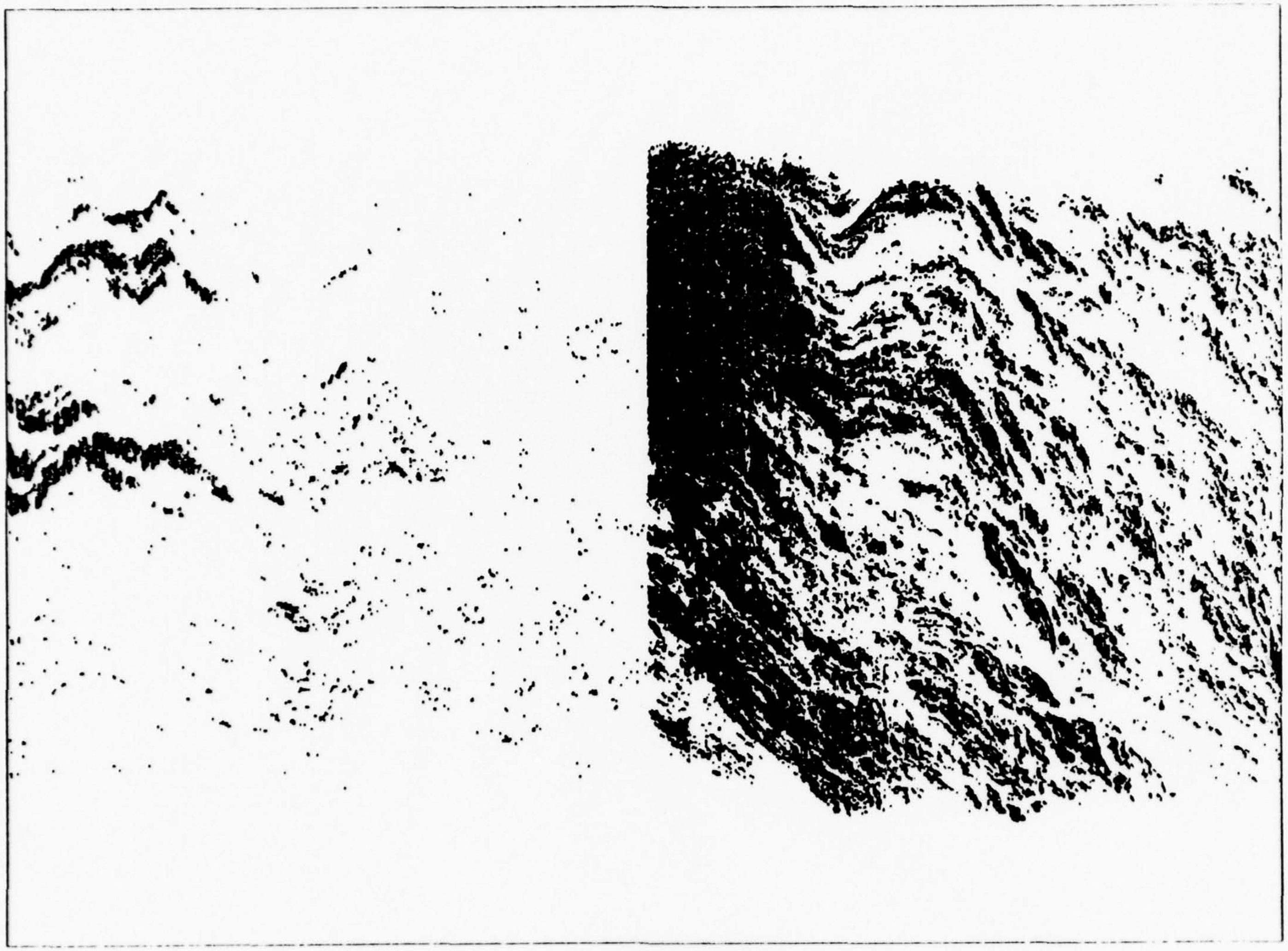
SHADE PLOT FILE 5 SPECTRAL BAND 3
THRESHOLD = $\hat{\mu} + 2.0\hat{\sigma}$
HEVB-MOUNTAINS (5.1-5.7 MICRONS)



SHADE PLOT FILE 5 SPECTRAL BAND 3
THRESHOLD = $\hat{\mu} + 2.5\hat{\sigma}$
NEVB-MOUNTAINS (5.1-5.7 MICRONS)

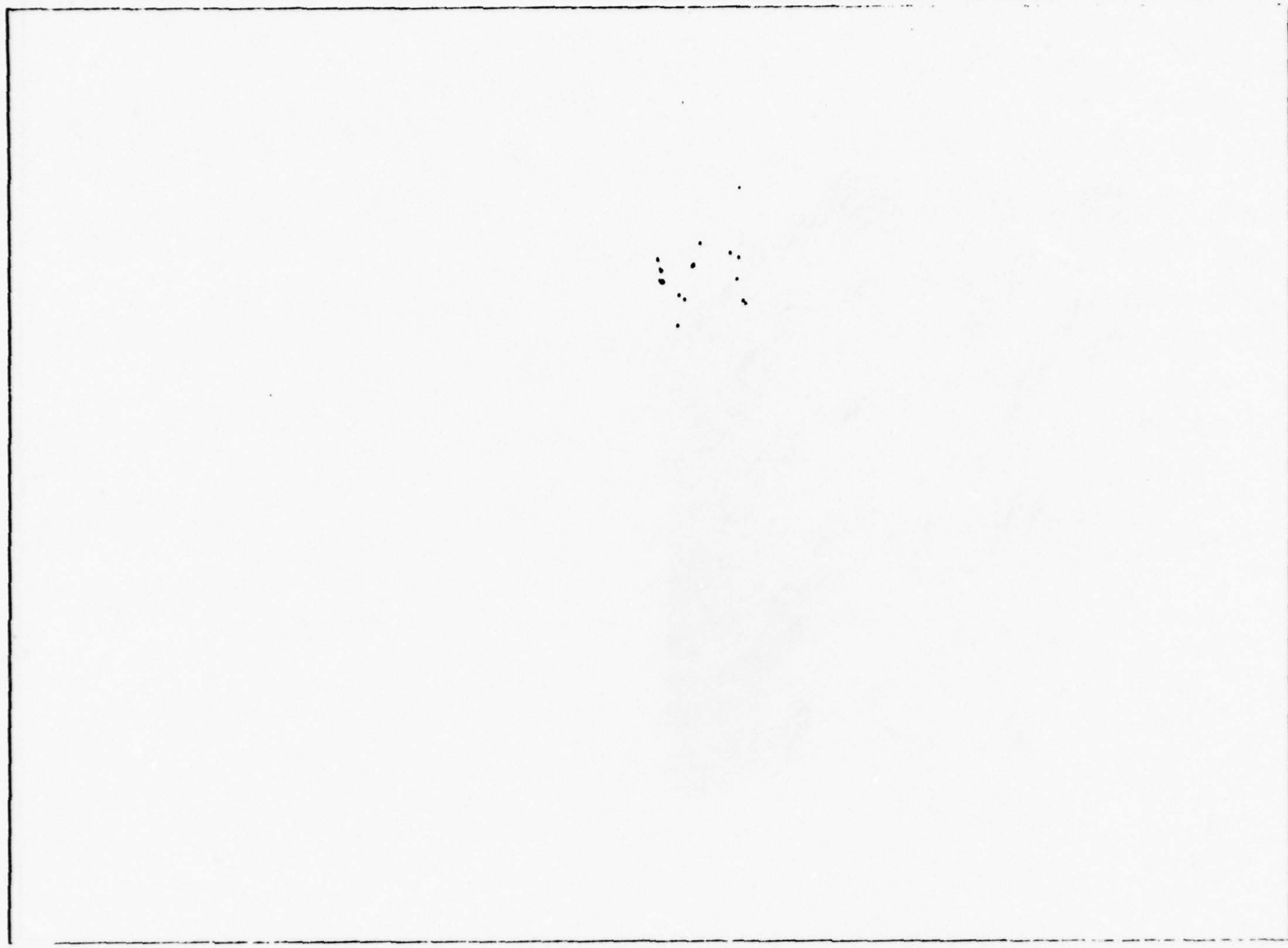


SHADE PLOT FILE 5 SPECTRAL BAND 3
THRESHOLD = $\hat{\mu} + 3.0\hat{\sigma}$
NEVB-MOUNTAINS (5.1-5.7 MICRONS)

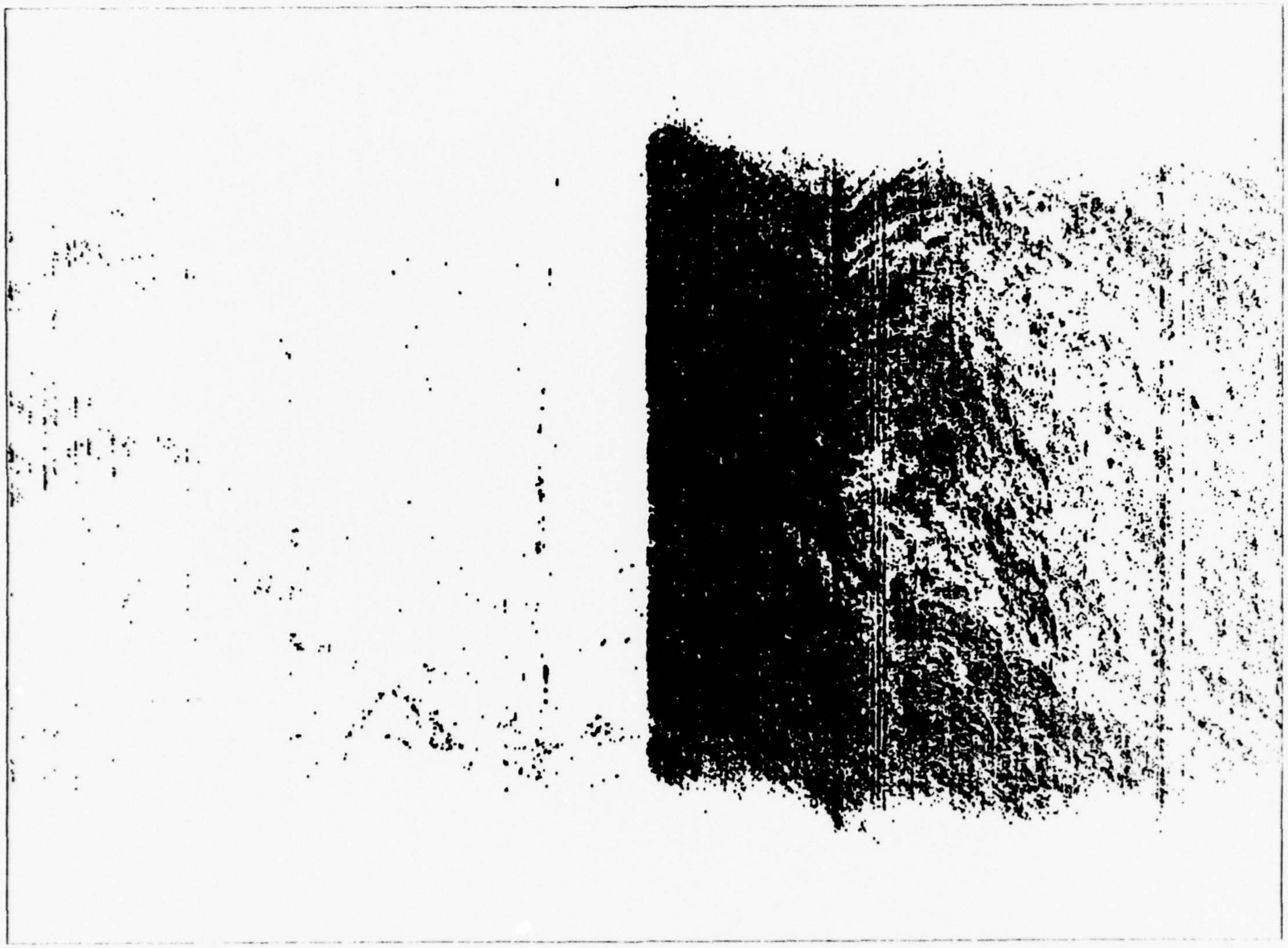


SHADE PLOT FILE 7 SPECTRAL BAND 1
THRESHOLD = $\hat{\mu} + \hat{\sigma}$
NEVC-DESERT (3.9-4.7 MICRONS)

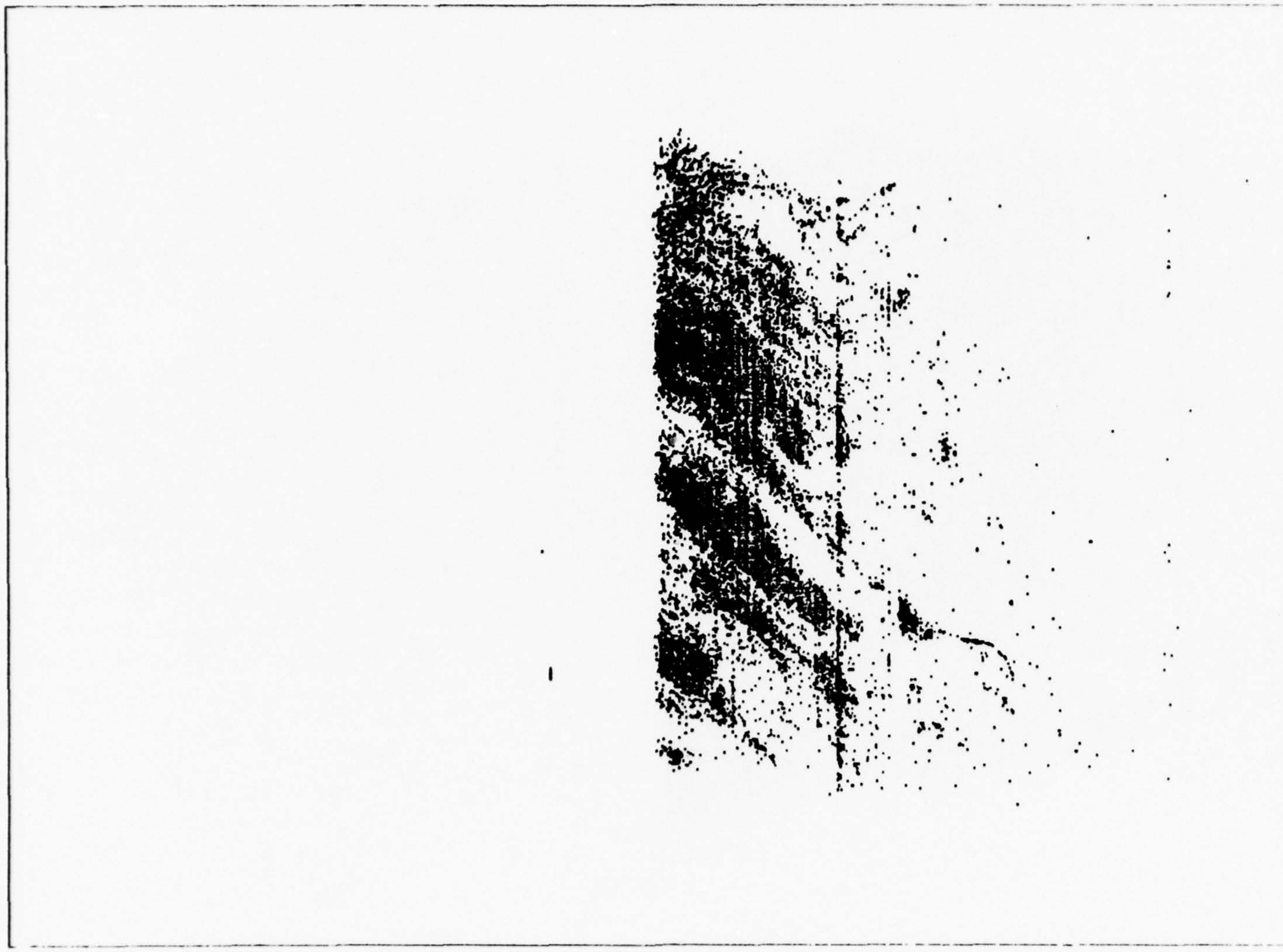
SHADE PLOT FILE 7 SPECTRAL BAND 1
THRESHOLD = $\hat{\mu} + 1.5\hat{\sigma}$
NEVC-DESERT (3.9-4.7 MICRONS)



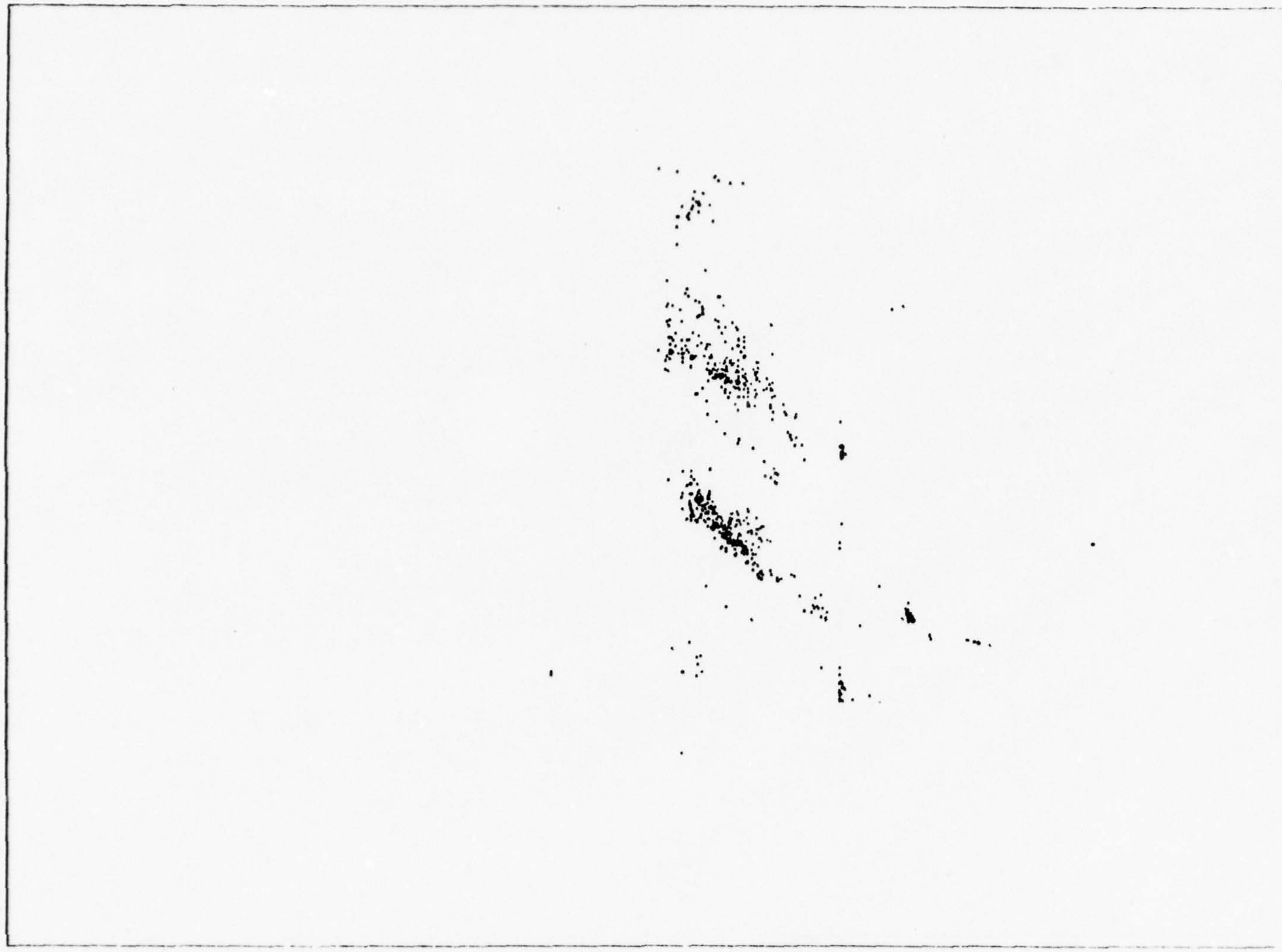
SHADE PLOT FILE 7 SPECTRAL BAND 1
THRESHOLD = $\hat{\mu} + 2\hat{\sigma}$
NEVC-DESERT (3.9-4.7 MICRONS)



SHADE PLOT FILE 7 SPECTRAL BAND 2
THRESHOLD = $\hat{\mu} + \hat{\sigma}$
NEVC-DESERT (3.5-3.9 MICRONS)

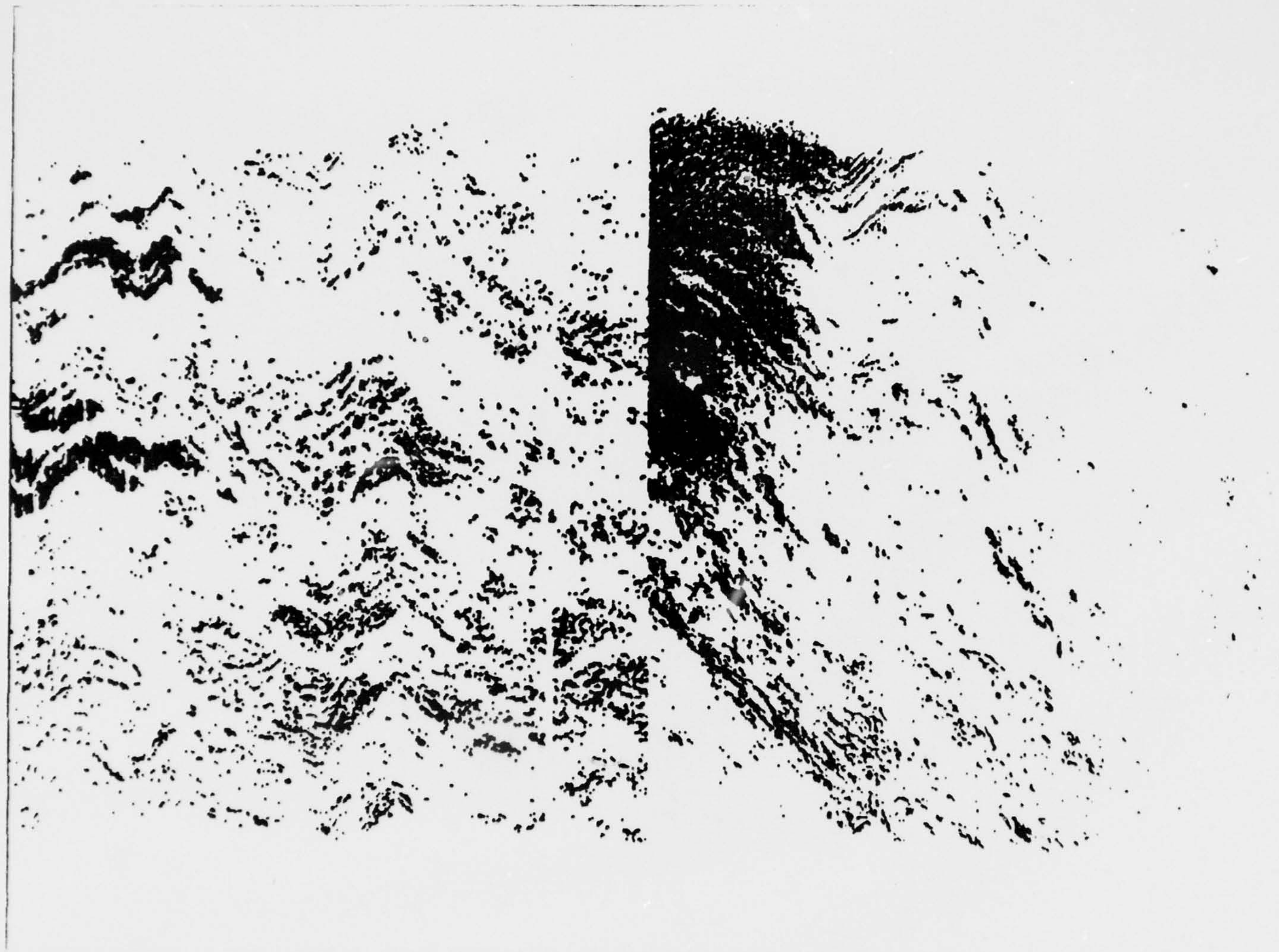


SHADE PLOT FILE 7 SPECTRAL BAND 2
THRESHOLD = $\hat{\mu} + 1.5\hat{\sigma}$
NEVC-DESERT (3.5-3.9 MICRONS)



SHADE PLOT FILE 7 SPECTRAL BAND 2
THRESHOLD = $\mu + 2\hat{\sigma}$
NEVC-DESERT (3.5-3.9 MICRONS)

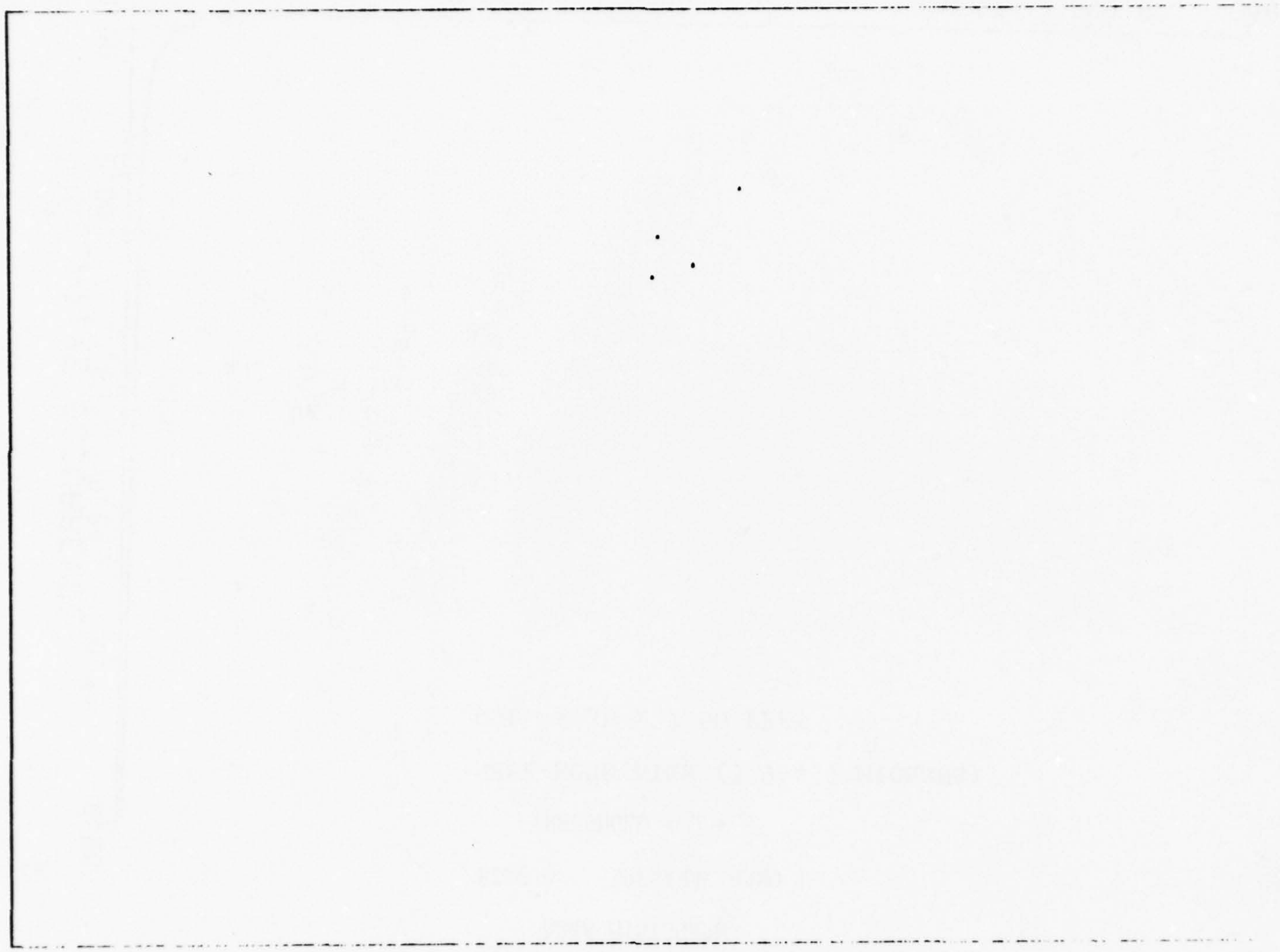
SHADE PLOT FILE 7 SPECTRAL BAND 2
THRESHOLD = $\hat{\mu} + 2.5\hat{\sigma}$
NEVC-DESERT (3.5-3.9 MICRONS)



SHADE PLOT   FILE 7   SPECTRAL BAND 3
THRESHOLD = $\hat{\mu} + \hat{\sigma}$

NEVC-DESERT (9.0-11.4 MICRONS)

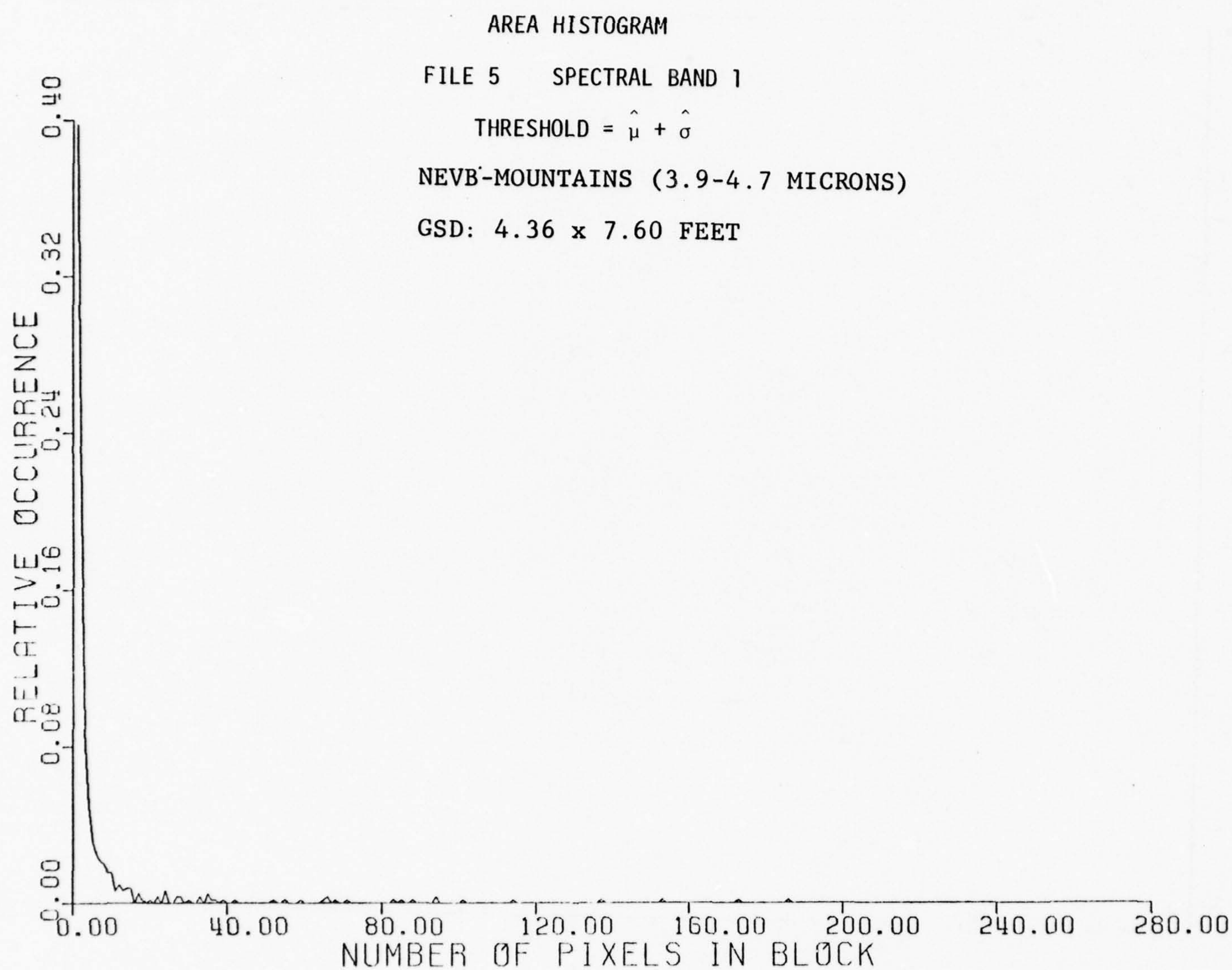
SHADE PLOT FILE 7 SPECTRAL BAND 3
THRESHOLD = $\hat{\mu} + 1.5\hat{\sigma}$
NEVC-DESERT (9.0-11.4 MICRONS)

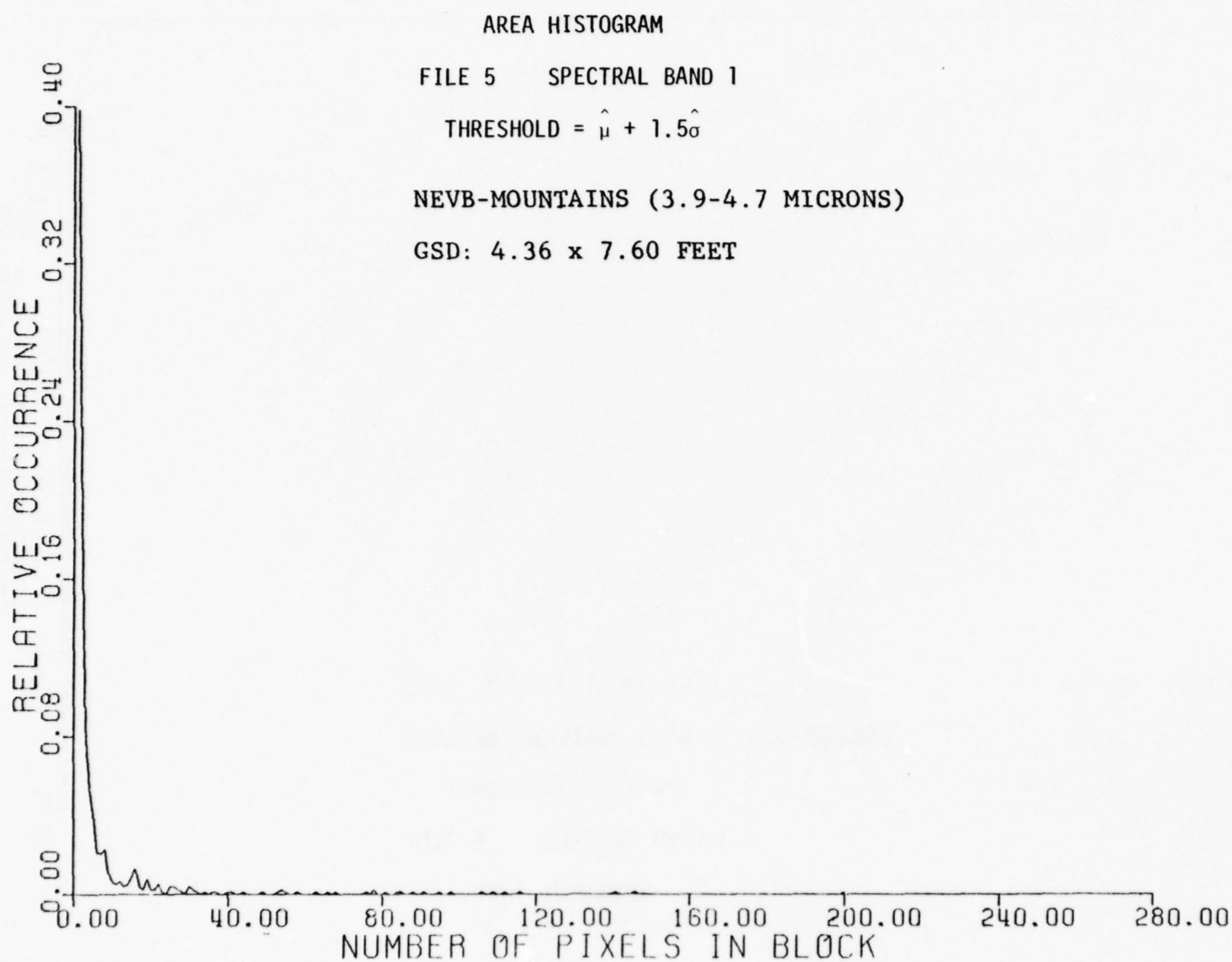


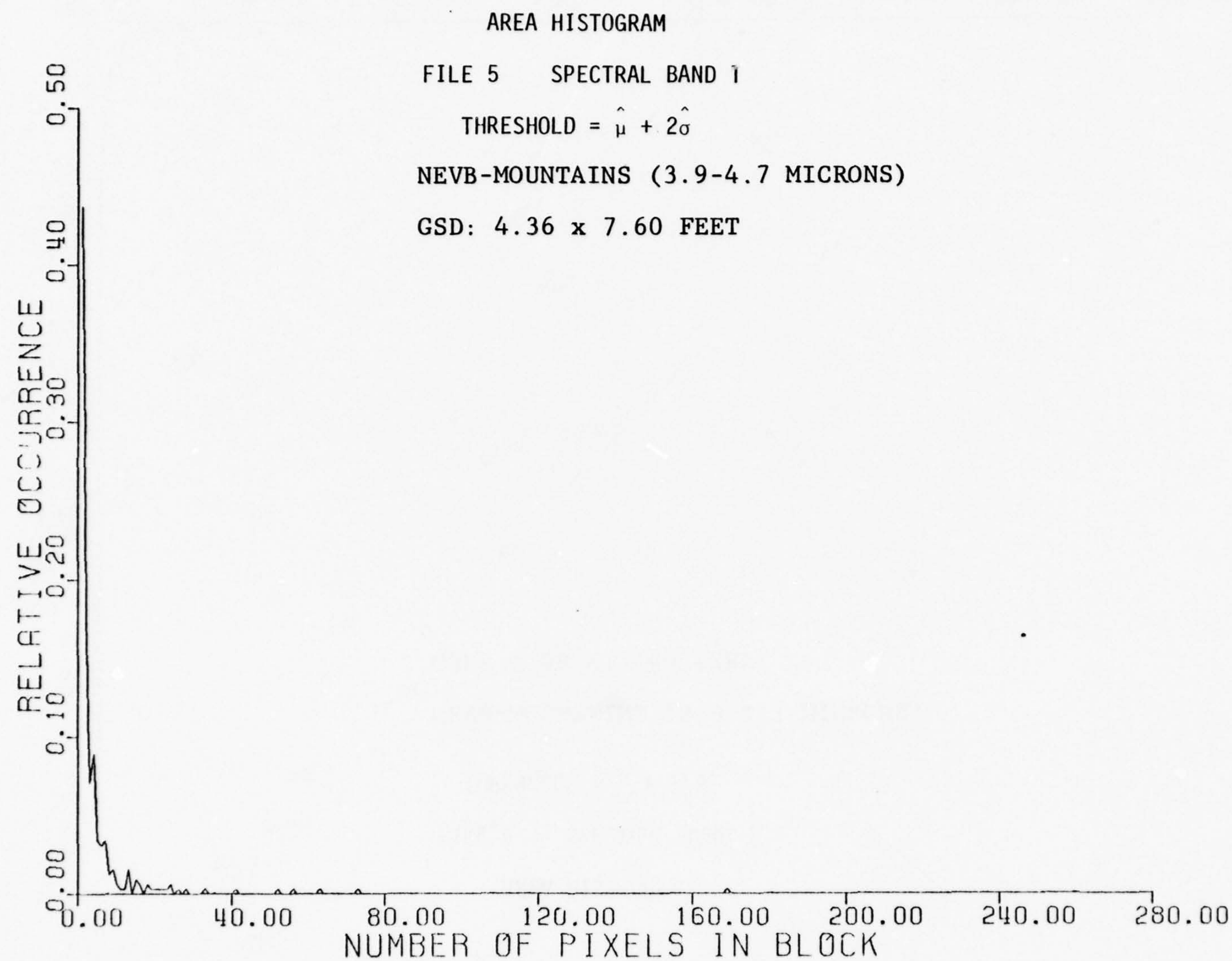
SHADE PLOT FILE 7 SPECTRAL BAND 3

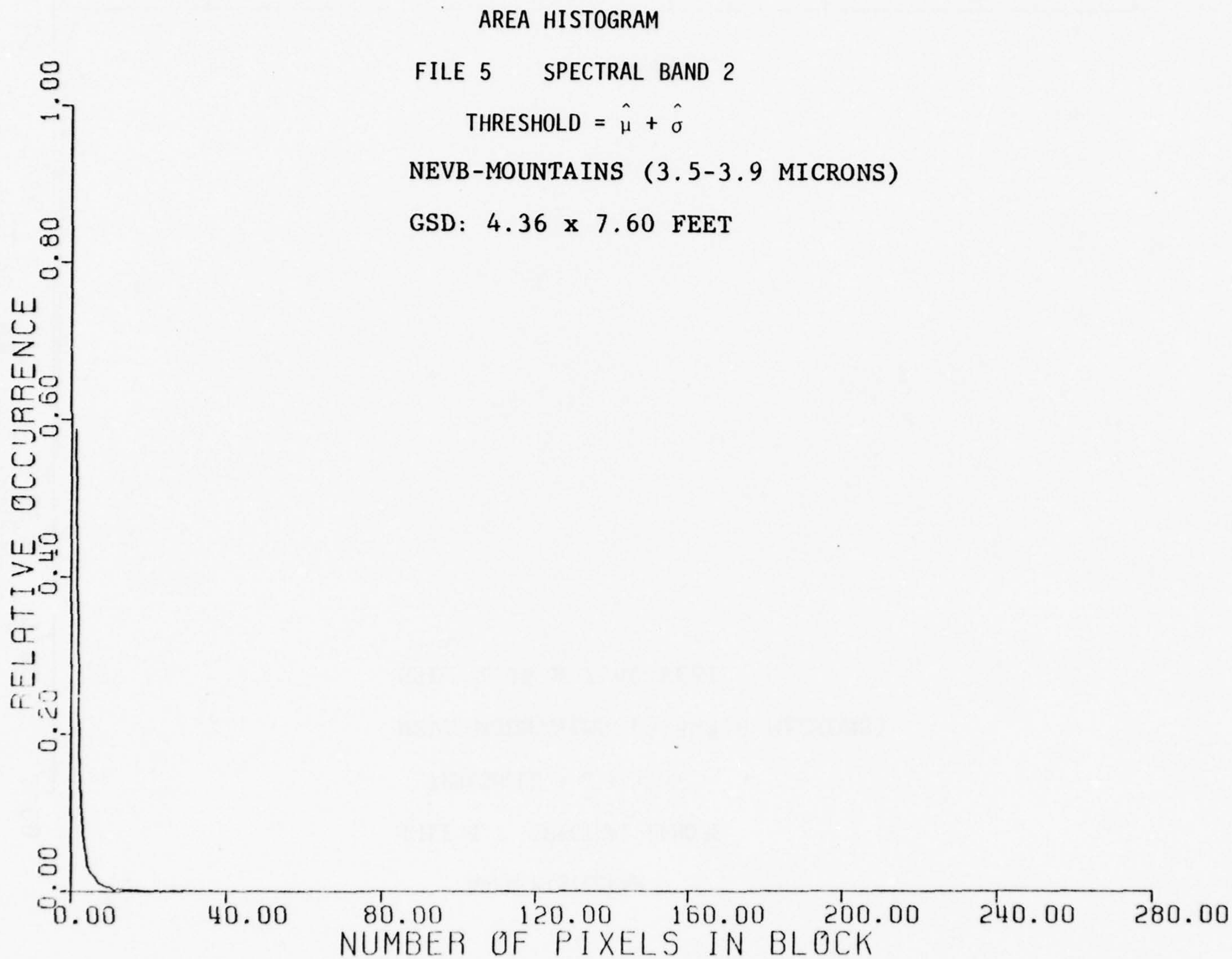
THRESHOLD = $\hat{\mu} + 2\hat{\sigma}$

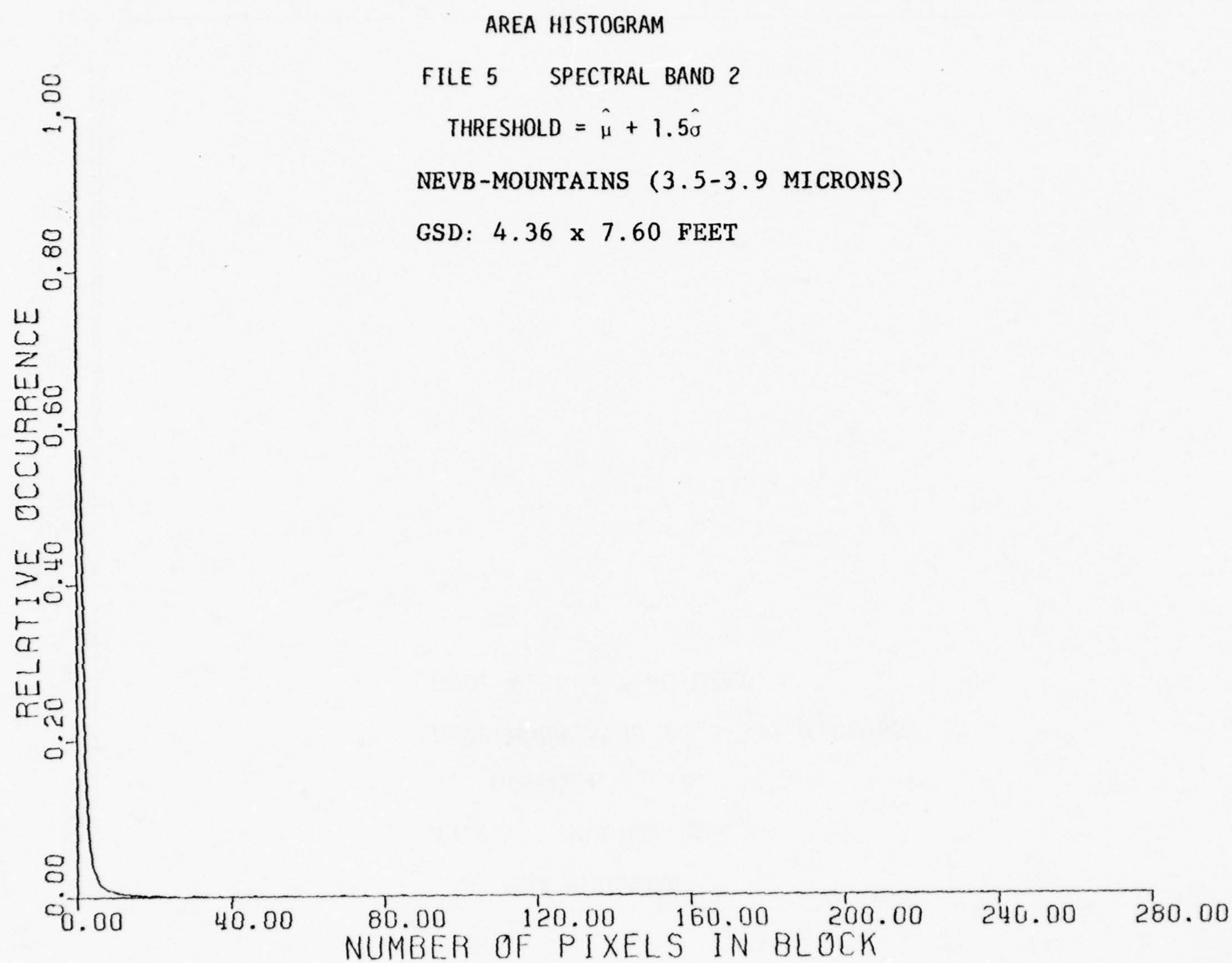
NEVC-DESERT (9.0-11.4 MICRONS)


AREA HISTOGRAM
FILE 5 SPECTRAL BAND 1
THRESHOLD = $\hat{\mu} + \hat{\sigma}$
NEVB-MOUNTAINS (3.9-4.7 MICRONS)
GSD: 4.36 x 7.60 FEET
RELATIVE OCCURRENCE
0.00
0.08
0.16
0.24
0.32
0.40
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
NUMBER OF PIXELS IN BLOCK


AREA HISTOGRAM
FILE 5 SPECTRAL BAND 1
THRESHOLD = $\hat{\mu} + 1.5\hat{\sigma}$
NEVB-MOUNTAINS (3.9-4.7 MICRONS)
GSD: 4.36 x 7.60 FEET
RELATIVE OCCURRENCE
0.00
0.08
0.16
0.24
0.32
0.40
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
NUMBER OF PIXELS IN BLOCK


AREA HISTOGRAM
FILE 5 SPECTRAL BAND 1
THRESHOLD = $\hat{\mu} + 2\hat{\sigma}$
NEVB-MOUNTAINS (3.9-4.7 MICRONS)
GSD: 4.36 x 7.60 FEET
RELATIVE OCCURRENCE
0.00
0.10
0.20
0.30
0.40
0.50
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
NUMBER OF PIXELS IN BLOCK


AREA HISTOGRAM
FILE 5 SPECTRAL BAND 2
THRESHOLD = $\hat{\mu} + \hat{\sigma}$
NEVB-MOUNTAINS (3.5-3.9 MICRONS)
GSD: 4.36 x 7.60 FEET
RELATIVE ØCCURRENCE
0.00
0.20
0.40
0.60
0.80
1.00
NUMBER ØF PIXELS IN BLØCK
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00


AREA HISTOGRAM
FILE 5 SPECTRAL BAND 2
THRESHOLD = $\hat{\mu} + 1.5\hat{\sigma}$
NEVB-MOUNTAINS (3.5-3.9 MICRONS)
GSD: 4.36 x 7.60 FEET
RELATIVE OCCURRENCE
0.00
0.20
0.40
0.60
0.80
1.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
NUMBER OF PIXELS IN BLOCK

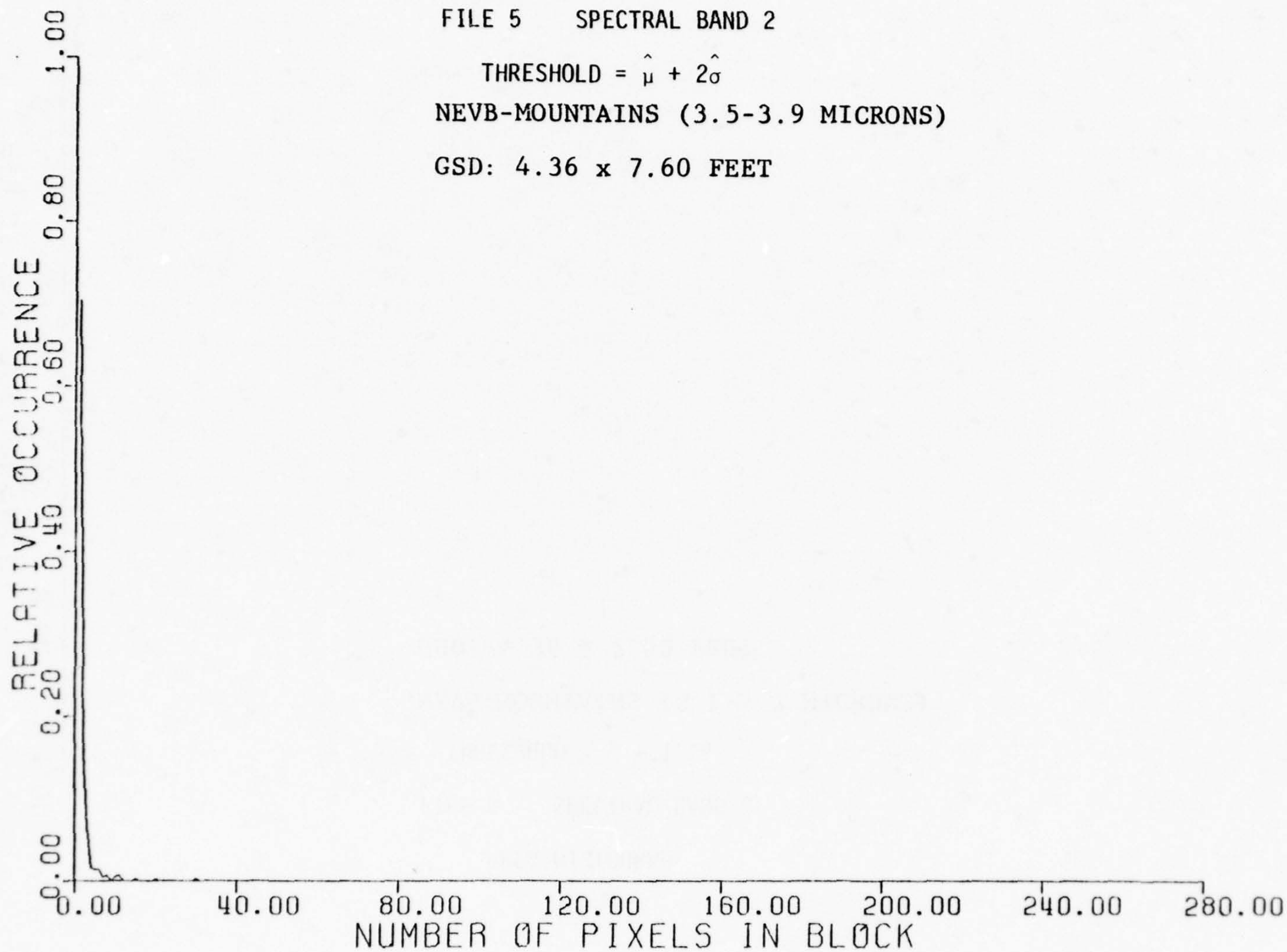
AREA HISTOGRAM

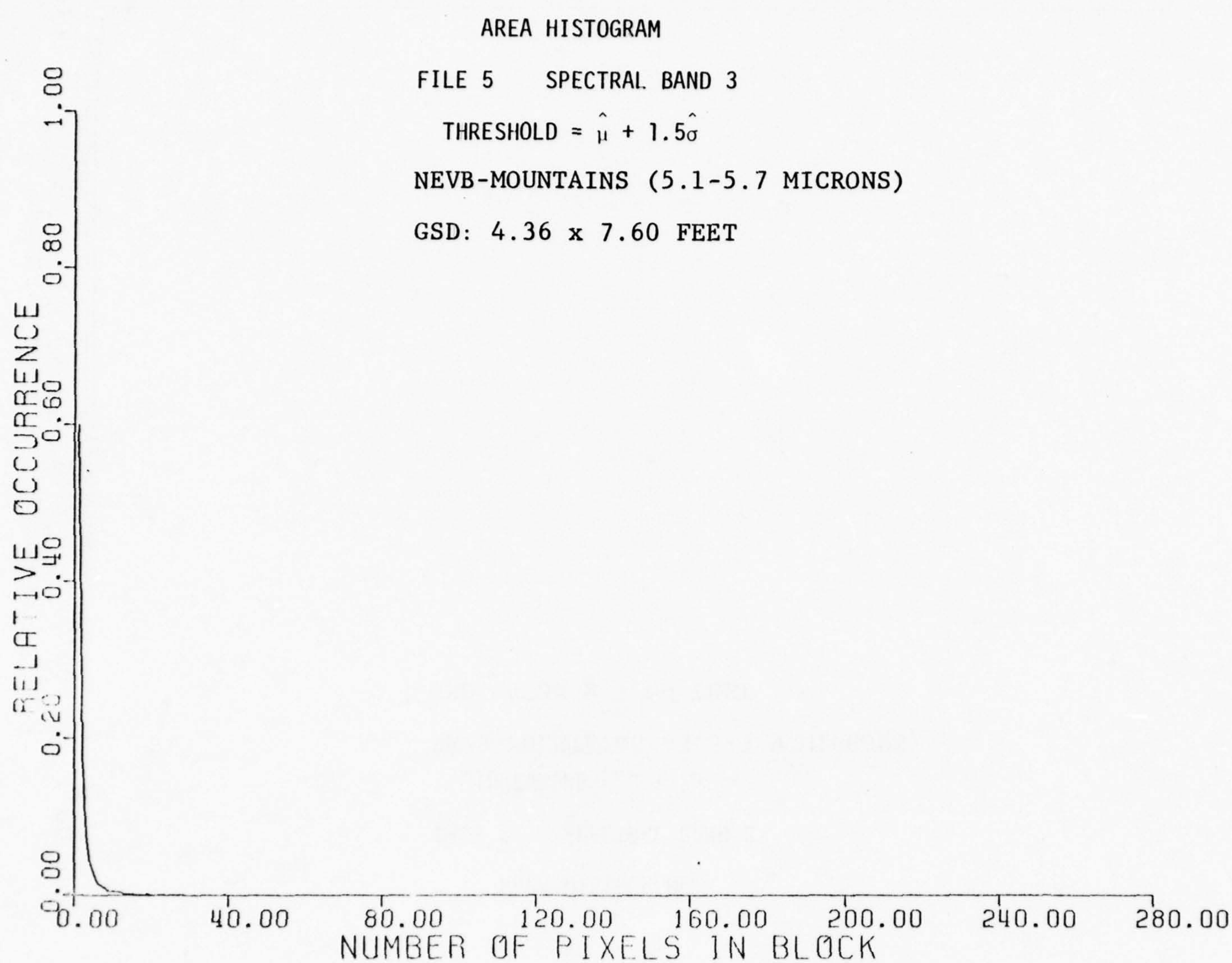
FILE 5 SPECTRAL BAND 2

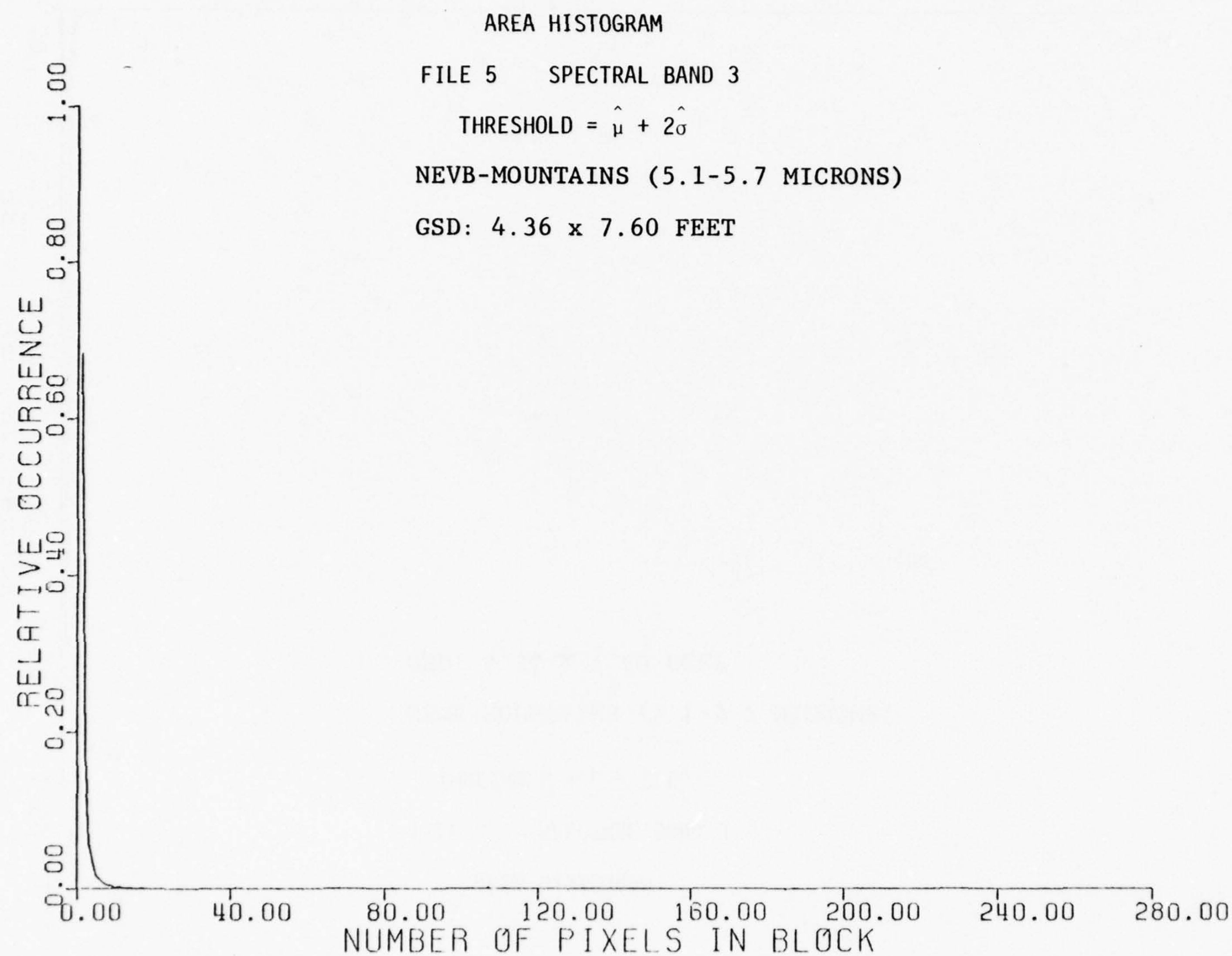
THRESHOLD = $\hat{\mu} + 2\hat{\sigma}$

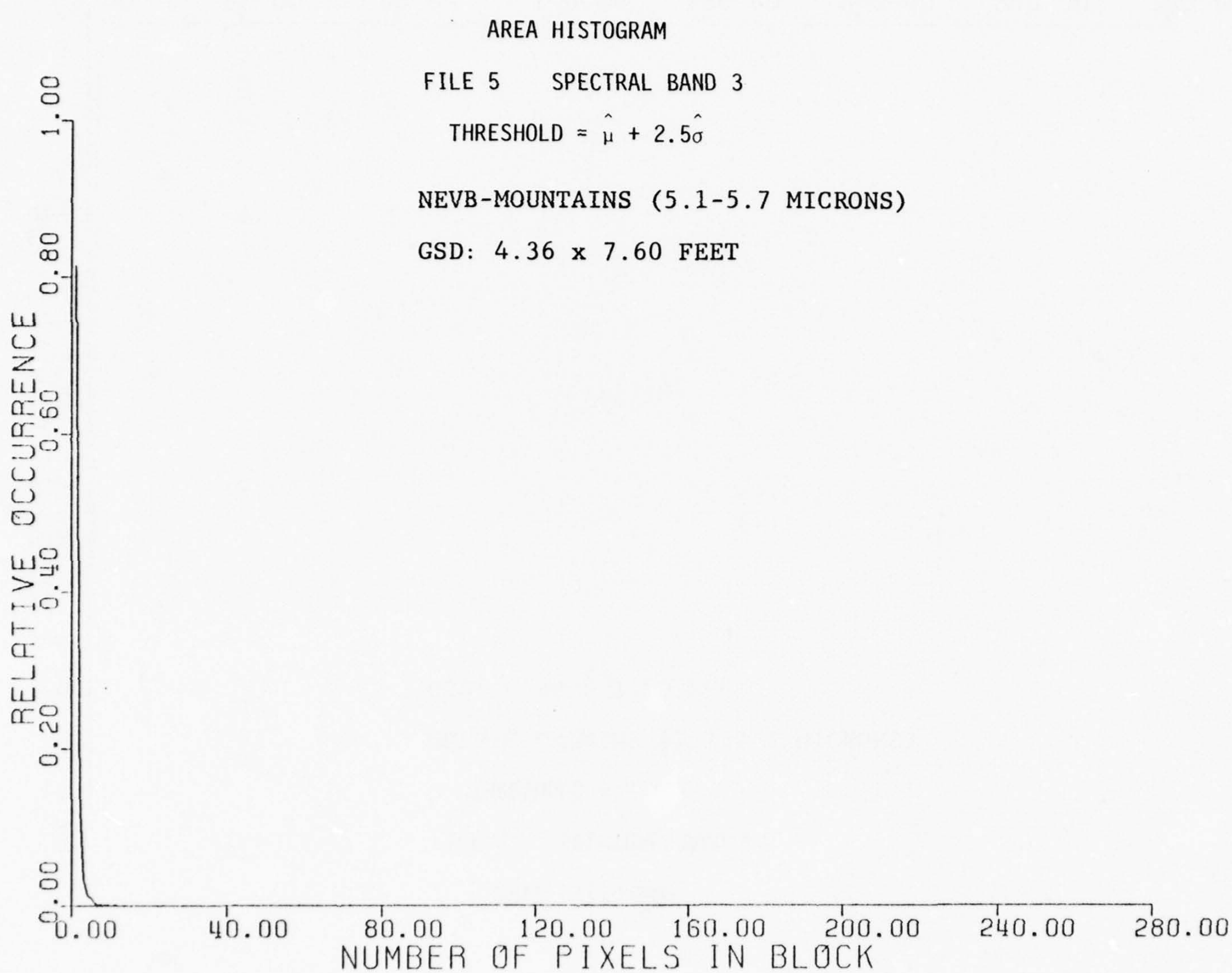
NEVB-MOUNTAINS (3.5-3.9 MICRONS)

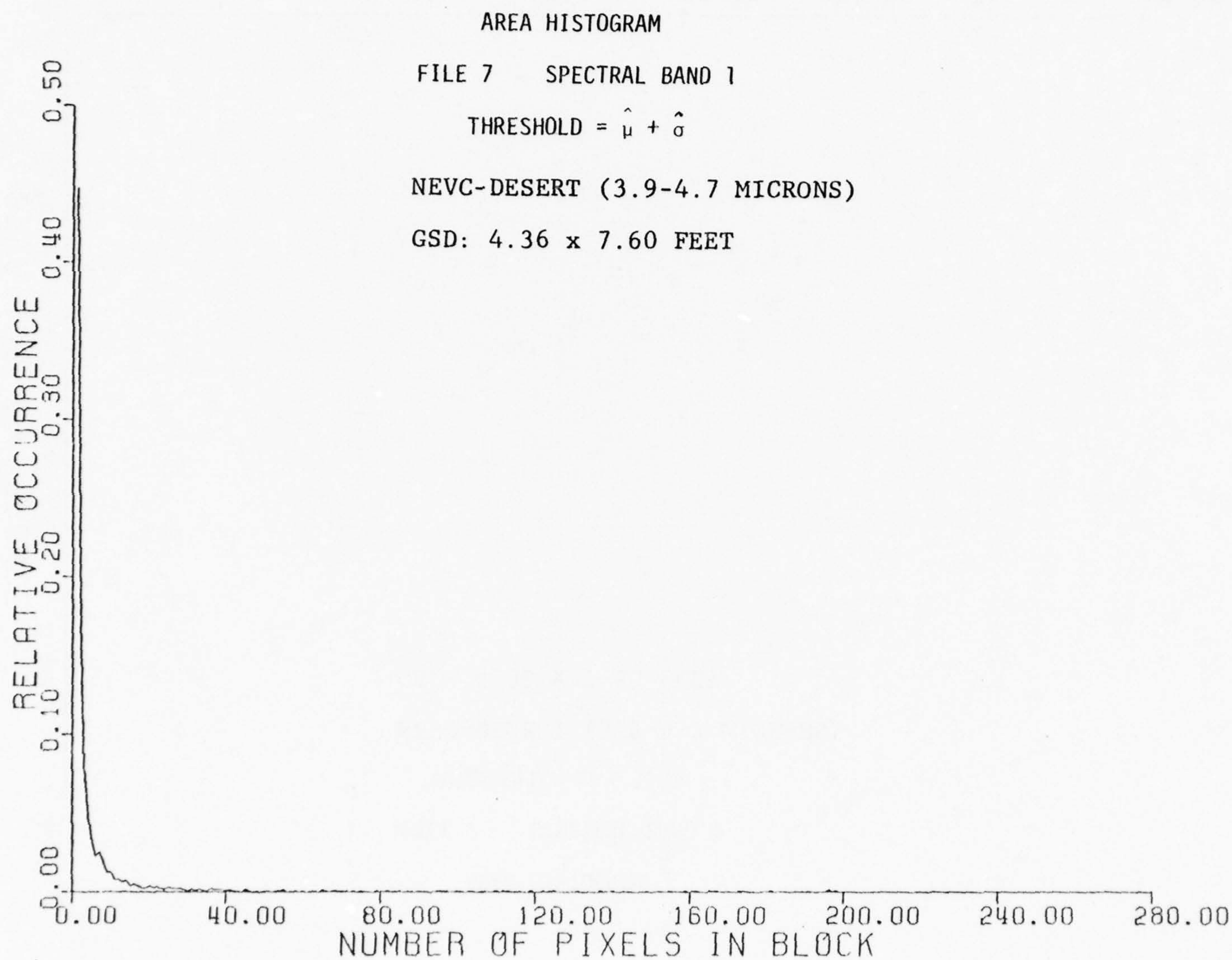
GSD: 4.36 x 7.60 FEET

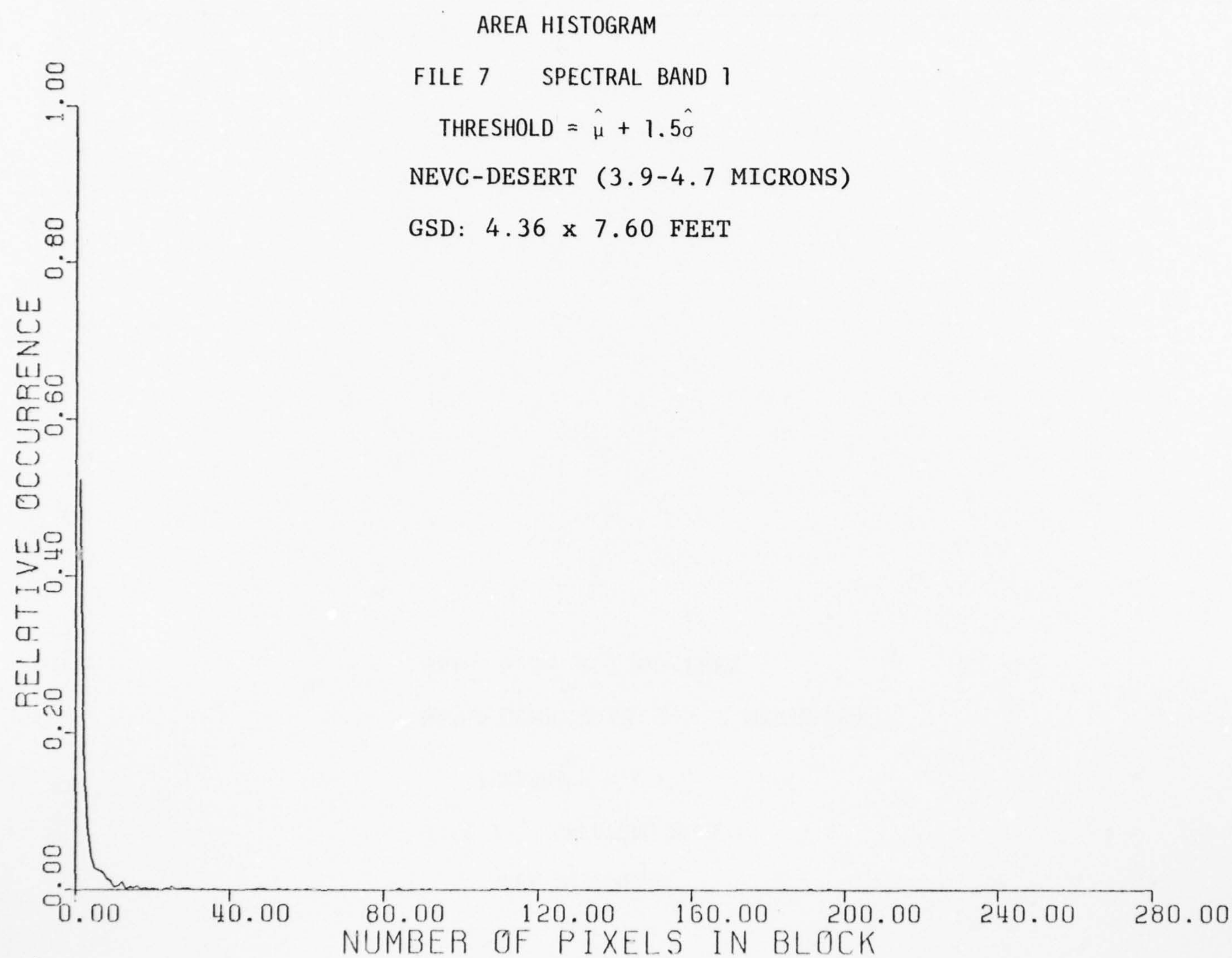


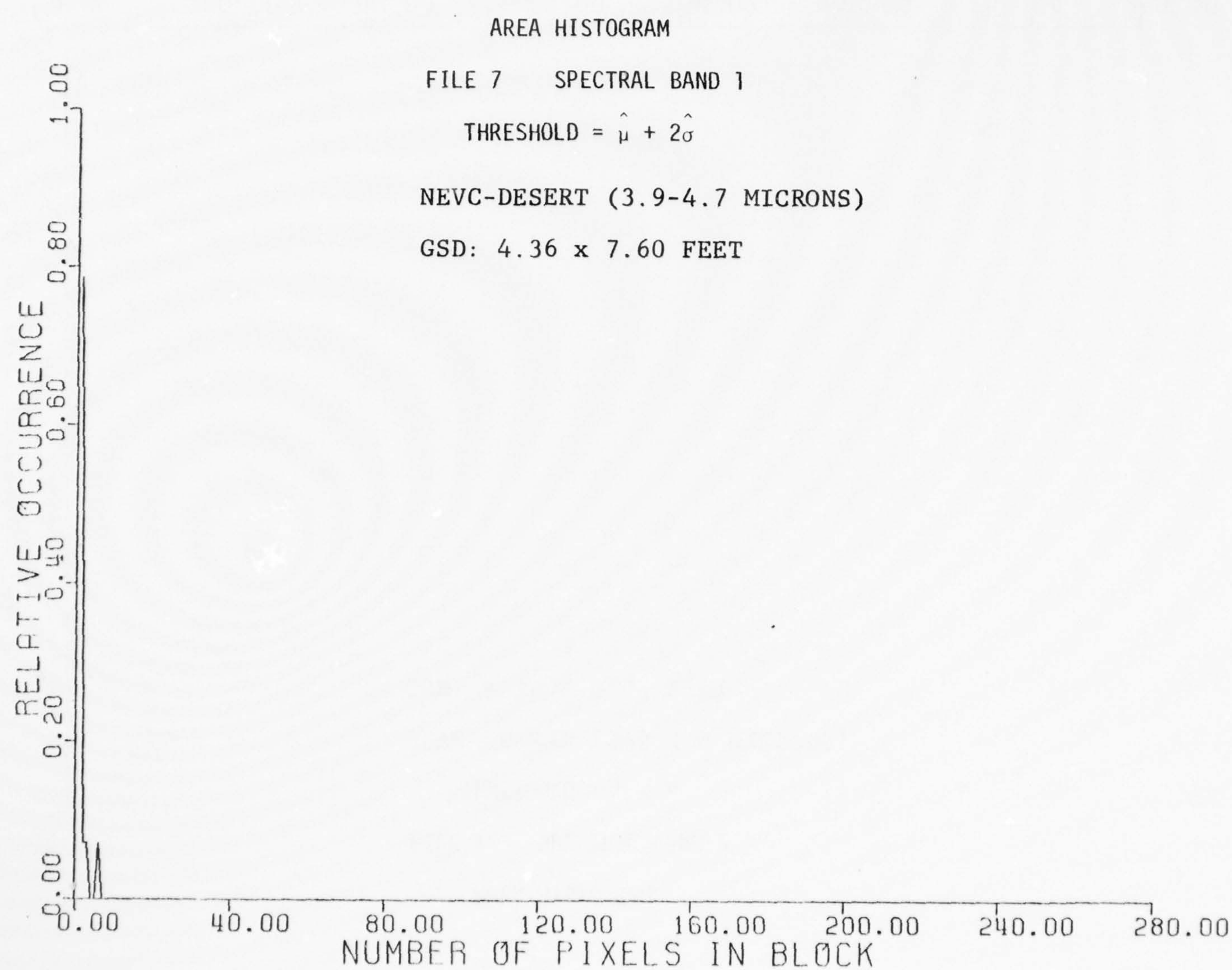

AREA HISTOGRAM
FILE 5 SPECTRAL BAND 3
THRESHOLD = $\hat{\mu} + 1.5\hat{\sigma}$
NEVB-MOUNTAINS (5.1-5.7 MICRONS)
GSD: 4.36 x 7.60 FEET
RELATIVE OCCURRENCE
0.00
0.20
0.40
0.60
0.80
1.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
NUMBER OF PIXELS IN BLOCK

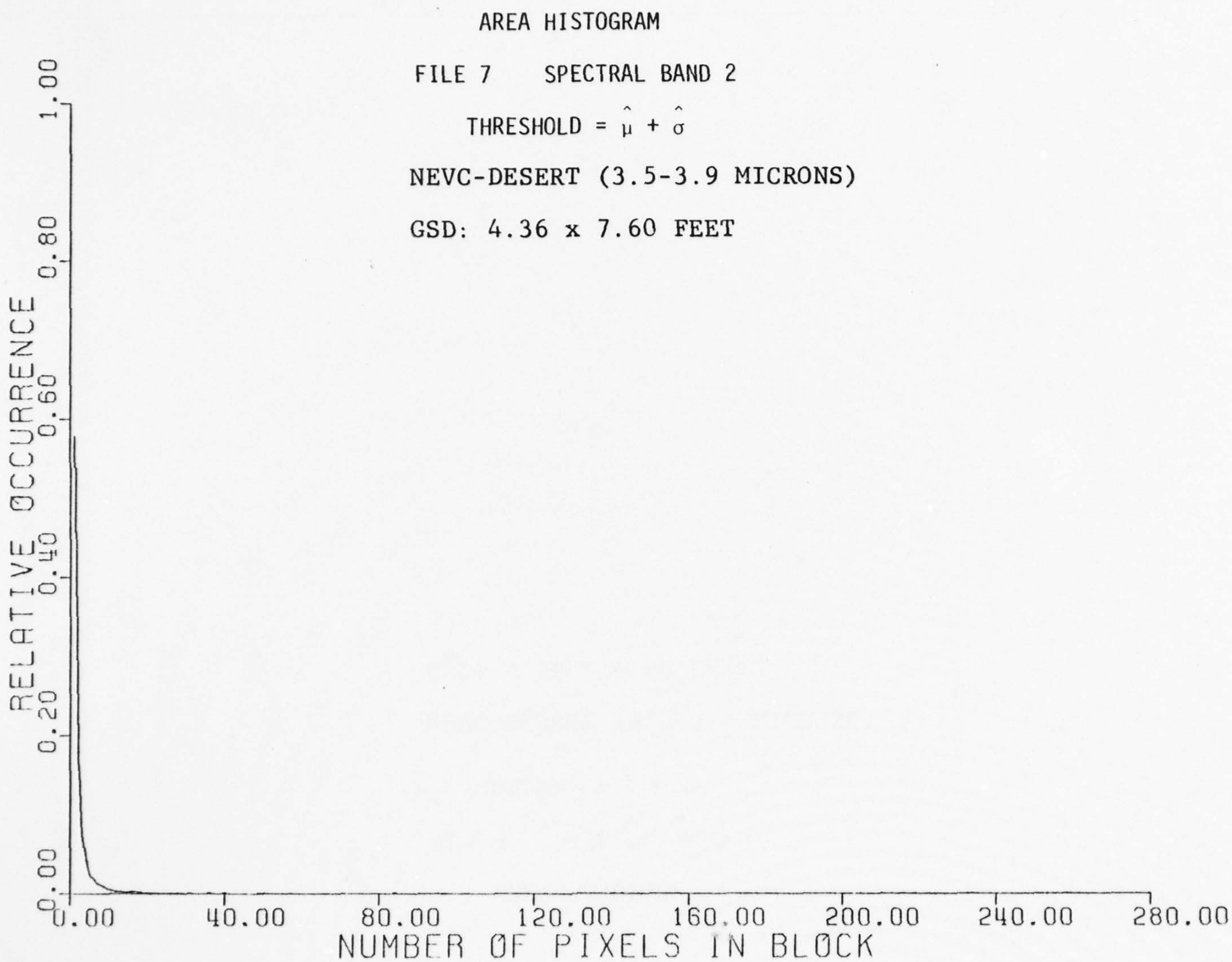

AREA HISTOGRAM
FILE 5 SPECTRAL BAND 3
THRESHOLD = $\hat{\mu} + 2\hat{\sigma}$
NEVB-MOUNTAINS (5.1-5.7 MICRONS)
GSD: 4.36 x 7.60 FEET
RELATIVE OCCURRENCE
0.00
0.20
0.40
0.60
0.80
1.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
NUMBER OF PIXELS IN BLOCK

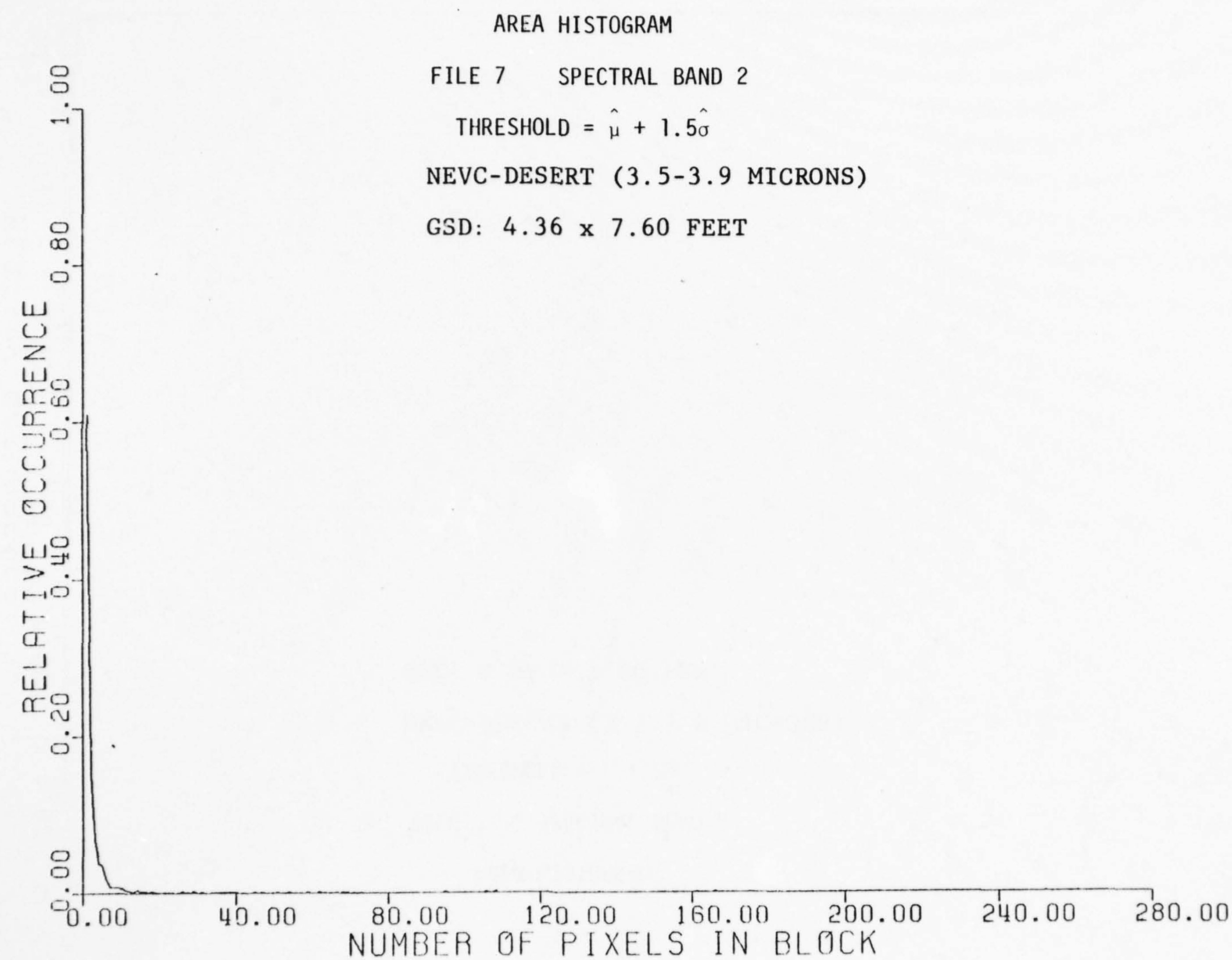

AREA HISTOGRAM
FILE 5 SPECTRAL BAND 3
THRESHOLD = $\hat{\mu} + 2.5\hat{\sigma}$
NEVB-MOUNTAINS (5.1-5.7 MICRONS)
GSD: 4.36 x 7.60 FEET
RELATIVE OCCURRENCE
0.00
0.20
0.40
0.60
0.80
1.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
NUMBER OF PIXELS IN BLOCK


AREA HISTOGRAM
FILE 7 SPECTRAL BAND 1
THRESHOLD = $\hat{\mu} + \hat{\sigma}$
NEVC-DESERT (3.9-4.7 MICRONS)
GSD: 4.36 x 7.60 FEET
RELATIVE OCCURRENCE
0.00
0.10
0.20
0.30
0.40
0.50
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
NUMBER OF PIXELS IN BLOCK

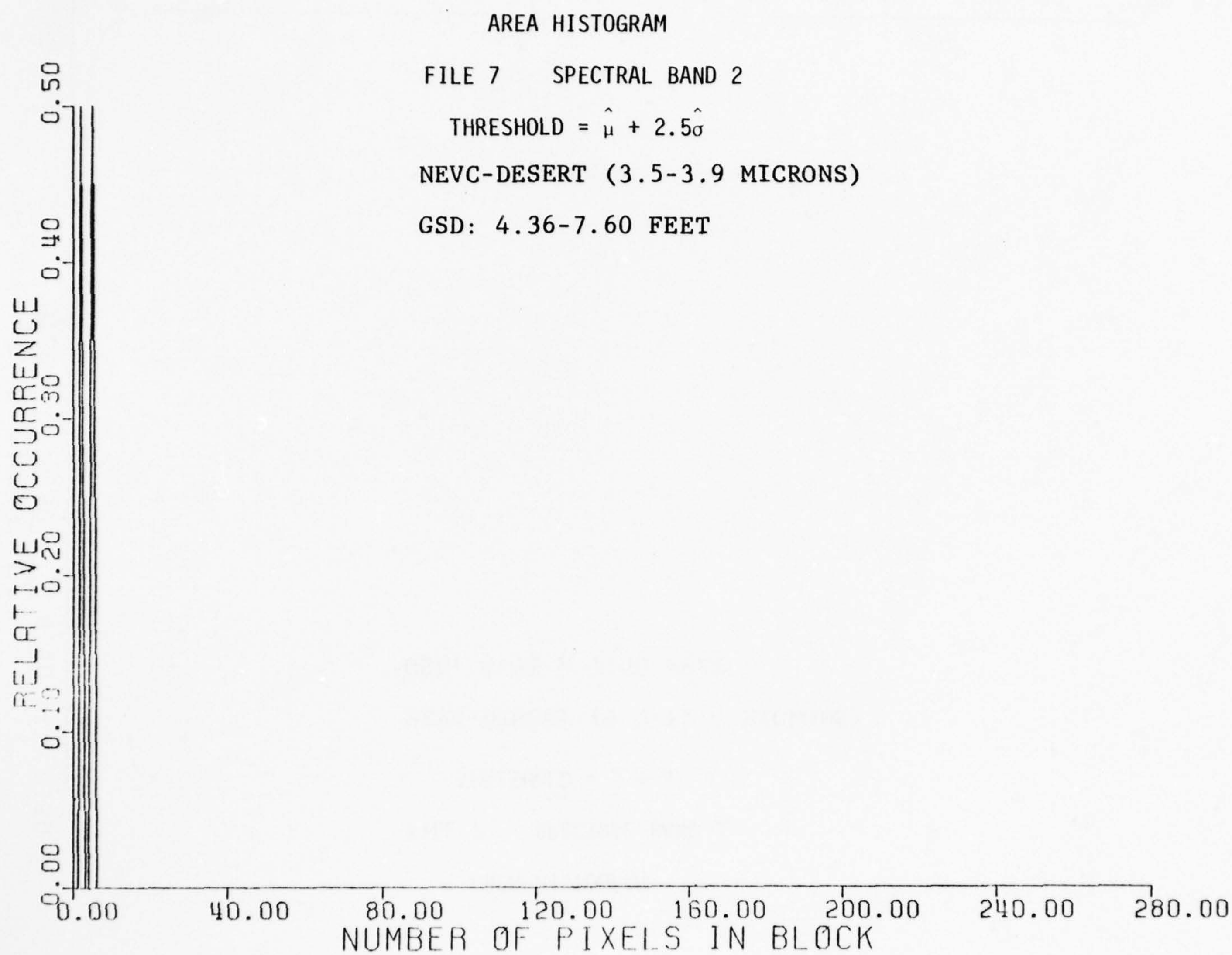

AREA HISTOGRAM
FILE 7 SPECTRAL BAND 1
THRESHOLD = $\hat{\mu} + 1.5\hat{\sigma}$
NEVC-DESERT (3.9-4.7 MICRONS)
GSD: 4.36 x 7.60 FEET
RELATIVE OCCURRENCE
0.00
0.20
0.40
0.60
0.80
1.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
NUMBER OF PIXELS IN BLOCK

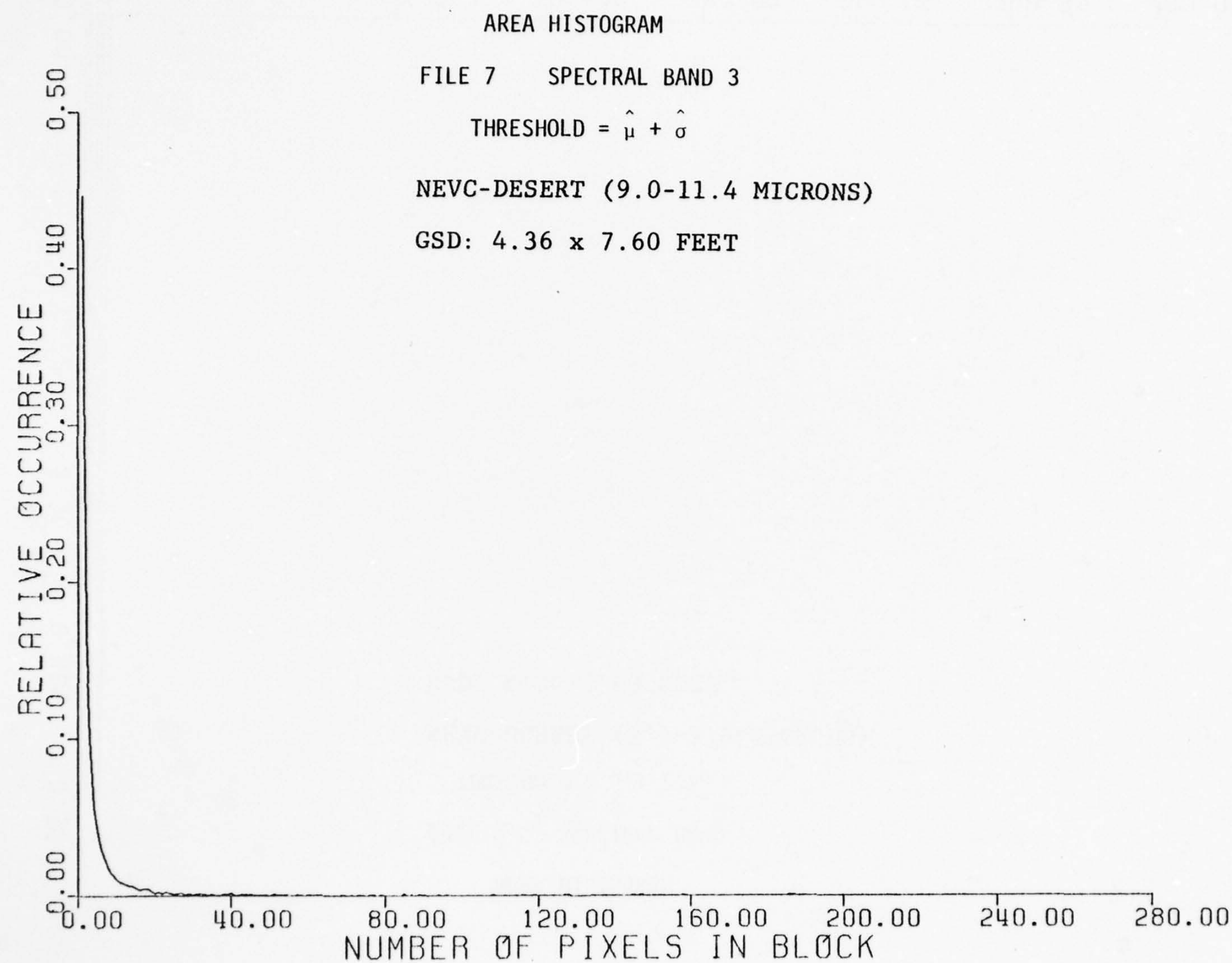

AREA HISTOGRAM
FILE 7 SPECTRAL BAND 1
THRESHOLD = $\hat{\mu} + 2\hat{\sigma}$
NEVC-DESERT (3.9-4.7 MICRONS)
GSD: 4.36 x 7.60 FEET
RELATIVE OCCURRENCE
0.00
0.20
0.40
0.60
0.80
1.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
NUMBER ØF PIXELS IN BLØCK

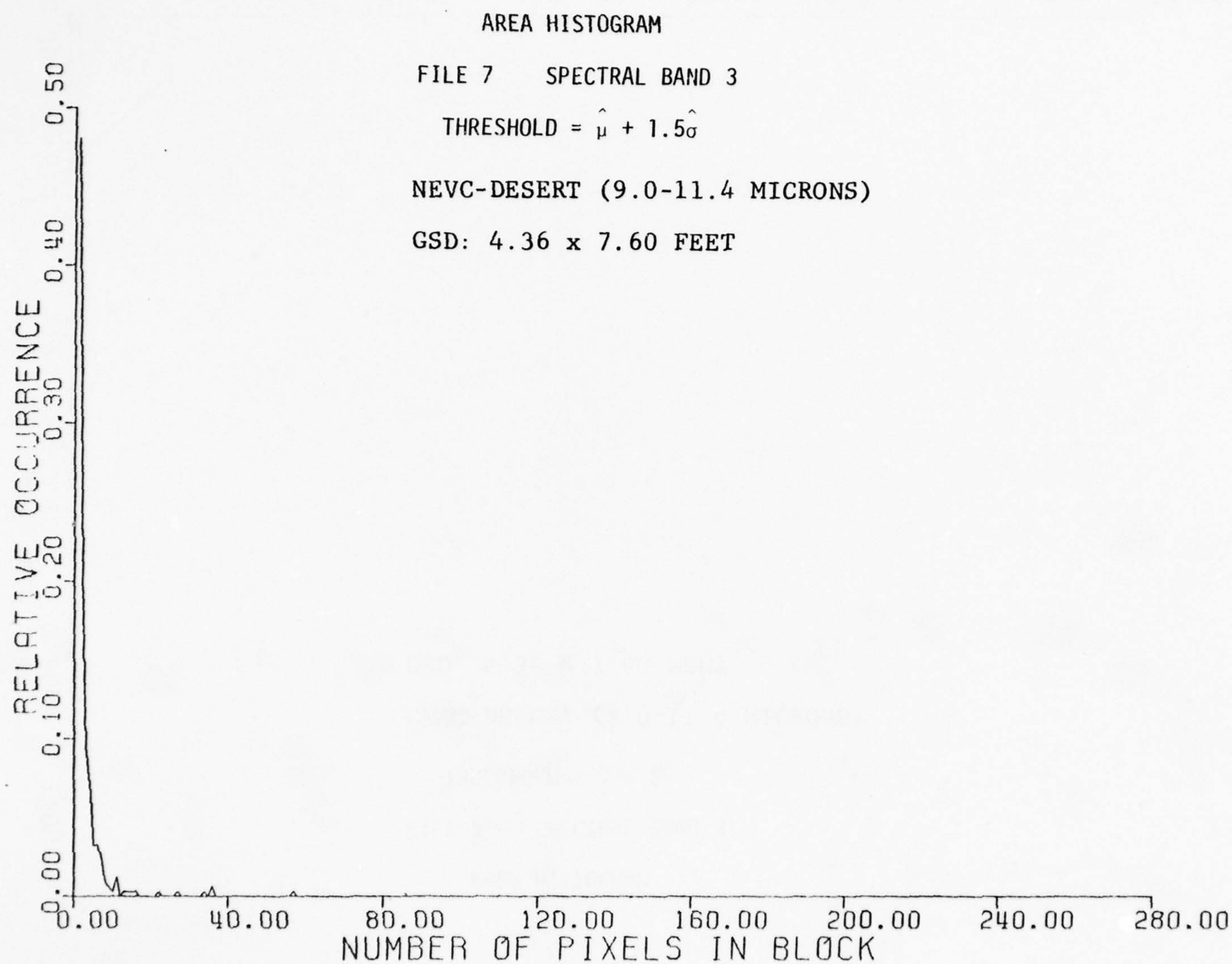

AREA HISTOGRAM
FILE 7 SPECTRAL BAND 2
THRESHOLD = $\hat{\mu} + \hat{\sigma}$
NEVC-DESERT (3.5-3.9 MICRONS)
GSD: 4.36 x 7.60 FEET
RELATIVE OCCURRENCE
0.00
0.20
0.40
0.60
0.80
1.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
NUMBER OF PIXELS IN BLOCK


AREA HISTOGRAM
FILE 7 SPECTRAL BAND 2
THRESHOLD = $\hat{\mu} + 1.5\hat{\sigma}$
NEVC-DESERT (3.5-3.9 MICRONS)
GSD: 4.36 x 7.60 FEET
RELATIVE OCCURRENCE
0.00
0.20
0.40
0.60
0.80
1.00
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
NUMBER OF PIXELS IN BLOCK


AREA HISTOGRAM
FILE 7 SPECTRAL BAND 2
THRESHOLD = $\hat{\mu} + 2\hat{\sigma}$
NEVC-DESERT (3.5-3.9 MICRONS)
GSD: 4.36 x 7.60 FEET
RELATIVE OCCURRENCE
0.00
0.20
0.40
0.60
0.80
1.00
NUMBER OF PIXELS IN BLOCK
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00


AREA HISTOGRAM
FILE 7 SPECTRAL BAND 2
THRESHOLD = $\hat{\mu} + 2.5\hat{\sigma}$
NEVC-DESERT (3.5-3.9 MICRONS)
GSD: 4.36-7.60 FEET
RELATIVE OCCURRENCE
0.00
0.10
0.20
0.30
0.40
0.50
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
NUMBER OF PIXELS IN BLOCK


AREA HISTOGRAM
FILE 7 SPECTRAL BAND 3
THRESHOLD = $\hat{\mu} + \hat{\sigma}$
NEVC-DESERT (9.0-11.4 MICRONS)
GSD: 4.36 x 7.60 FEET
RELATIVE OCCURRENCE
0.00
0.10
0.20
0.30
0.40
0.50
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00
NUMBER OF PIXELS IN BLOCK


AREA HISTOGRAM
FILE 7 SPECTRAL BAND 3
THRESHOLD = $\hat{\mu} + 1.5\hat{\sigma}$
NEVC-DESERT (9.0-11.4 MICRONS)
GSD: 4.36 x 7.60 FEET
RELATIVE OCCURRENCE
0.00
0.10
0.20
0.30
0.40
0.50
NUMBER OF PIXELS IN BLOCK
0.00
40.00
80.00
120.00
160.00
200.00
240.00
280.00

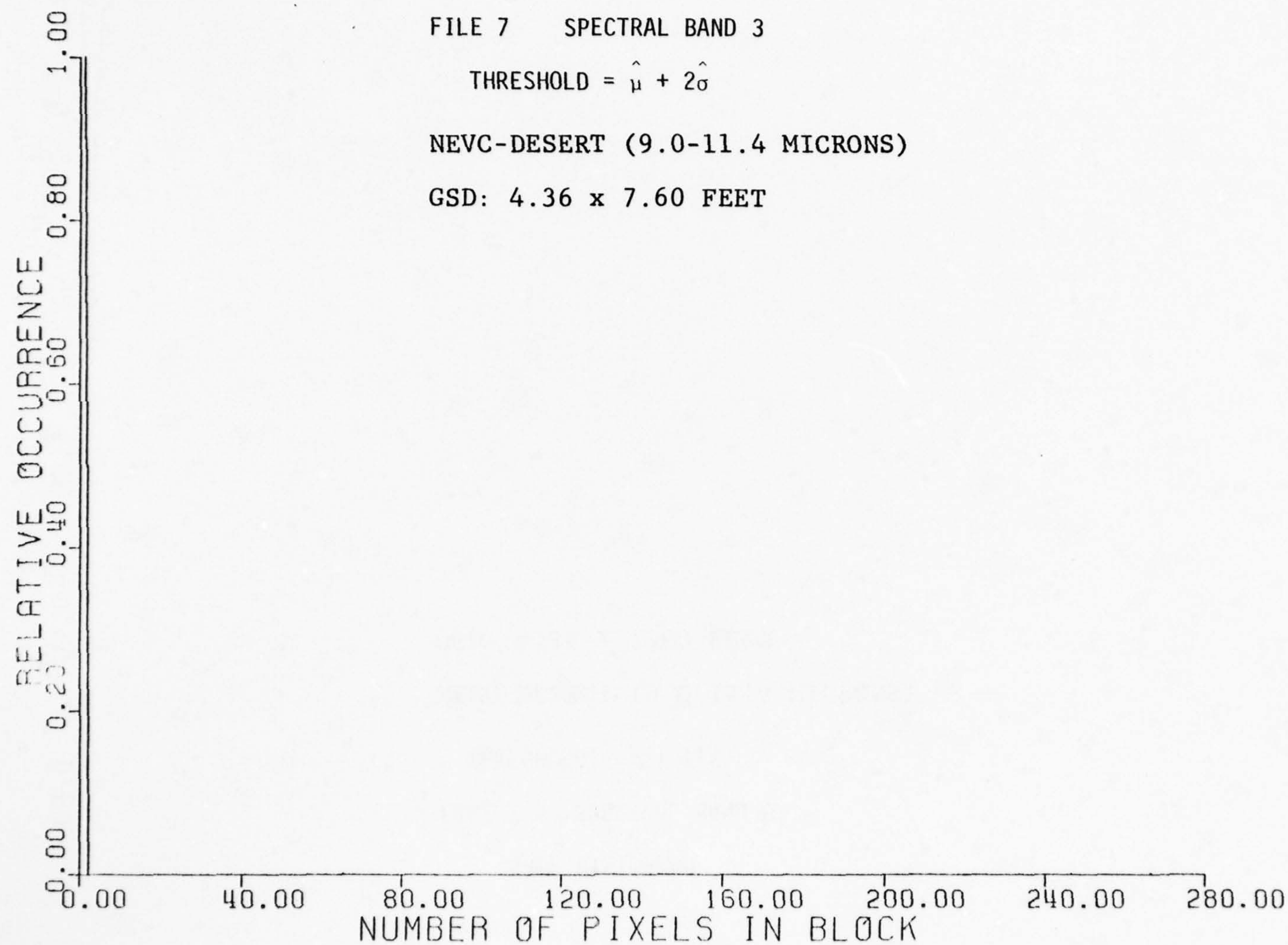
AREA HISTOGRAM

FILE 7   SPECTRAL BAND 3

THRESHOLD = $\hat{\mu} + 2\hat{\sigma}$

NEVC-DESERT (9.0-11.4 MICRONS)

GSD: 4.36 x 7.60 FEET



SECTION VI. SUMMARY AND CONCLUSIONS

A brief theoretical development was presented to establish a basis for using background statistics in a discrimination model. The development was limited to threshold detection and did not include detailed spectral, spatial or temporal dependence. An advanced model for discrimination would probably include these features as well.

The major emphasis for the contract was the development of statistics from empirical, background, banded, radiometric data which shows threshold and area features. The analysis was primarily for individual scenes and was not to duplicate existing methods for inter-spectral band correlation. Thus the results serve as one specific class of analysis methods which should be used together with other methods in a discrimination model.

Application of the analysis to more suitable background scenarios should provide useful inputs for infrared warning receiver false alarm analysis, when used in conjunction with realistic target signature measurements.

APPENDIX

Software Listing

```
C      PLOTIT GENERATES AMPLITUDE HISTOGRAMS AND CALCULATES AMPLITUDE
C      STATISTICS FROM DIGITIZED MULTI SPECTRAL SCANNER DATA STORED SCAN
C      LINE PER RECORD ON MAGNETIC TAPE. PLOTIT IS SET UP TO READ TAPES
C      ON WHICH DATA VALUES FOR THREE SPECTRAL BANDS HAVE BEEN
C      INTERLEAVED. THIS PROGRAM ASSUMES THAT THERE ARE 1938 DATA
C      VALUES PER RECORD AND THAT 646 VALUES BELONG TO EACH SPECTRAL
C      BAND. IT ALSO ASSUMES THAT THE MAGNITUDE OF DATA VALUES RANGES
C      FROM 0 TO 255.  JOB CONTROL LANGUAGE MUST BE INCLUDED TO IDENTIFY
C      UNIT 2 AS TAPE CONTAINING FILE TO BE USED.
       DIMENSION X(258),Y(258),ID(1938)
       REAL MF
       INTEGER SB,QU,QUSD
C************  PARAMETERS WHICH CHANGE WITH DATA SETS  *****************
       NBR=898
       FILE=5
       SB=1
       AF=277.476
       MF=.085632
       UMIN=3.5
       UMAX=3.9
C*************************************************************************
C      NBR=NUMBER OF RECORDS IN FILE
C      FILE=FILE FROM WHICH DATA IS TAKEN   USED ONLY FOR LABELING
C      SB=SPECTRAL BAND OF INTEREST  1,2,OR 3
C      AF AND MF ARE CALABRATION CONSTANTS SUPPLYED WITH TAPES
C      UMIN=LOWER LIMIT OF SPECTRAL BAND (MICRONS)
C      UMAX=UPPER LIMIT OF SPECTRAL BAND (MICRONS)
C*************************************************************************
       NPS=256
       VALUE=SB
       N=0
       U=0.
       X2=0.
C************ SET UP Y ARRAY ********************************************
       DO 5 I=1,256
5      Y(I)=0.
       DO 10 K=1,NBR
       READ(2) ID
       DO 10 I=SB,1938,3
       N=N+1
       J=ID(I)+1
10     Y(J)=Y(J)+1
       DO 20 K=1,256
       IF(Y(K).EQ.0.) GO TO 20
       Y(K)=Y(K)/N
20      CONTINUE
C************ SET UP X ARRAY ********************************************
       DO 21 I=1,256
       A=I-1
       CALL RAD(A,AF,MF,UMIN,UMAX,R)
21     X(I)=R
C************ PLOT HISTAGRAM ********************************************
       CALL LION(X,Y,NPS,VALUE,FILE)
C************ CALCULATE MEAN, VARIANCE, AND STANDARD DEVIATION**********
       DO 22 I=1,256
       U=X(I)*Y(I)+U
22     X2=Y(I)*X(I)**2+X2
       S=(N/(N-1))*(X2-U**2)
```

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```
      SD=SQRT(S)
C************ FIND INTEGER QUNTIZATION LEVEL CORRESPONDING TO THE MEAN
C              RADIANCE LEVEL ******************************************
      CALL QUNT(U,X,QU)
      WRITE(6,30) QU
C************ FIND QUNTIZATION LEVEL CORRESPONDING TO MEAN+(.25)(A)(SD)
C     RADIANCE LEVEL FOR A=1 TO 40 *************************************
      DO 23 K=1,40
      A=K*.25
      RIN=U+SD*A
      CALL QUNT(RIN,X,QUSD)
      WRITE(6,40) A,QUSD
23    CONTINUE
      WRITE(6,50) FILE
      WRITE(6,45) UMAX,UMIN,MF,AF
      WRITE(6,26) N
      WRITE(6,35)U,S,SD
26    FORMAT('0','NUMBER OF POINTS = ',I6 )
30    FORMAT('0','MEAN= ',I3)
35    FORMAT('0','MEAN = ',E11.4,' VARIANCE = ',E11.4,' SD = ',E11.4)
40    FORMAT('0','MEAN +',F4.2,'SD = ',I3)
45    FORMAT('0','UMAX= ',F4.1,' UMIN= ',F4.1,' MF= ',F9.7,' AF= ',F9.3)
50    FORMAT('0','******** FILE = ',F4.1,' ********')
      STOP
      END
C
C
C
C
C
      SUBROUTINE QUNT(RIN,X,Q)
C*************QUINT  FINDS THE QUNTIZATION LEVEL, Q,CORRESPONDING TO AN
C             INPUT RADIANCE LEVEL, RIN. IT USES THE XARRAY CALCULATED
C             IN MAIN PROGRAM. ******************************************
      DIMENSION X(258)
      INTEGER Q
      S=1.
      Q=300
      DO 5 I=1,256
      DIF=ABS(RIN-X(I))
      IF(DIF.GT.S) GO TO 5
      S=DIF
      Q=I-1
5     CONTINUE
      RETURN
      END
C
C
C
C
C
      SUBROUTINE RAD(A,AF,MF,UMIN,UMAX,R)
C*************RAD CALCULATES THE RADIANCE LEVEL, R,CORRESPONDING TO
C             THE INTEGER DATA VALUE, A. *******************************
      REAL MF
      T=A*MF+AF
      PI=3.1415927
      C1=3.7413E-08/PI
      C2=1.4388
      R=0.
```

```
      U=UMIN+.005
5     W= C1/((EXP(C2/(U*T))-1.)*U**5)
      R=R+W*.01
      U=U+.01
      IF(U.LT.UMAX) GO TO 5
      RETURN
      END
C
C
C
C
      SUBROUTINE LION(X,Y,NPS,VALUE,FILE)
C*************LION GENERATES ALL AXIS,SCALING, LABELING AND PLOTING
C              NECESSARY FOR MAKING HISTOGRAMS ***************************
      DIMENSION X(258) , Y(258)
       CALL PLOTS(0,0,0)
      CALL PLOT(0.,1.,2)
      CALL NUMBER(0.,9.,.35,FILE,0.,-1)
       CALL NUMBER(0.0,9.5,.35,VALUE,0.0,-1)
      CALL PLOT(3.,1.25,-3)
      CALL SCALE(Y,5.,NPS,1)
      CALL SCALE(X,7.0,NPS,1)
      CALL AXIS(0.,0.,'RELATIVE OCCURRENCE',19,5.,90.,Y(NPS+1),
     @ Y(NPS+2) )
C*************XAXIS IS AMODIFIED VERSION OF THE VERSATEC SUBROUTINE
C              AXIS. IT ALLOWS SUPERSCRIPTS TO APPEAR IN AXIS LABEL. ****
      CALL XAXIS(0.,0.,'RADIANCE  W M -2  SR -1 ',-24,7.,0.,X(NPS+1),
     @X(NPS+2))
      CALL LINE(X,Y,NPS,1,0,0)
      CALL PLOT(10.,-1.25,-3)
      CALL PLOT(0.,1.,2)
      CALL PLOT(0.,0.,+999)
      RETURN
      END
```

OUTPUT   JOB 8895   9V   GOGGANS   167 CARDS READ   3 PAGES PRINTED   0 CARDS PUNCHED

```
C      SHADE GENERATES A 2-D PLOT FROM DIGITIZED MULTISPECTRAL SCANNER
C      DATA STORED ON MAGNETIC TAPE. SHADE DARKENS SQUARES CORRESPONDING
C      TO DATA VALUES OVER A SELECTABLE THRESHOLD AND LEAVES WHITE ALL
C      OTHER ARES. SHADE MAKES THE SAME ASSUMPTIONS ABOUT THE DATA AS
C      PROGRAM PLOTIT. JOB CONTROL LANGUAGE MUST BE INCLUDED TO IDENTIFY
C      UNIT 2 AS TAPE CONTAINING FILE TO BE USED. A PLOT PARAMETER CARD
C      MUST ALSO BE INCLUDED TO SET PLOTER UNITS= ONE UNIT PER .01 INCH.
       INTEGER THRES
       INTEGER DATA(647),S,C ,A,T,SB,PRE
        DIMENSION ID(1938)
       DIMENSION  X(4),Y(4),IPAT9(16)
       DATA IPAT9/16*ZFFFF/
C************  PARAMETERS WHICH CHANGE WITH DATA SETS  *****************
       M=898
       THRES=169
       SB=3
       FILE=5.
C**********************************************************************
C       M=NUMBER OF RECORDS IN FILE
C      THRES=INTEGER DATA VALUE USED AS THRESHOLD
C      SB=SPECTRAL BAND OF INTEREST  1,2,OR 3
C      FILE=FILE FROM WHICH DATA IS TAKEN   USED ONLY FOR LABELING
C**********************************************************************
       T=THRES
       N=646
       CALL PLOTS(0,0,0)
       CALL TONE(0.,0.,IPAT9,-16)
C*************DARKEN 7 BY 4 INCH AREA TO READY PLOTER*******************
       X(1)=0.
       Y(1)=0.
       X(2)=0.
       Y(2)=700.
       X(3)=400.
       Y(3)=700.
       X(4)=400
       Y(4)=0.
       CALL TONE (X,Y,4,1)
       CALL PLOT(0.,0.,-999)
C*************LABEL PLOT***********************************************
       VALUE=T
       CALL NUMBER(0.,0.,35.,VALUE,0.,-1)
       VALUE=SB
       CALL NUMBER(0.,50.,35.,VALUE,0.,-1)
       CALL NUMBER(0.,100.,35.,FILE,0.,-1)
       CALL PLOT  (100.,200.,-3)
C*************FRAME PLOT***********************************************
       B=M
       CALL PLOT(B ,000.,2)
       CALL PLOT(B ,646.,2)
       CALL PLOT(0.,646.,2)
       CALL PLOT(0.,000.,2)
       CALL TONE(0.,0.,IPAT9,-16)
C*************GENERATE PLOT********************************************
       PRE=0
       DO 100 I=1,M
       READ(2) ID
       C=0
       DO 10 A=SB,1938,3
```

AD-A068 152 AUBURN UNIV ALA DEPT OF ELECTRICAL ENGINEERING F/G 17/5
INFRARED TARGET/BACKGROUND DISCRIMINATION - BACKGROUND SPECTRAL--ETC(U)
NOV 78 L J PINSON, P M GOGGANS F33615-77-C-1188

UNCLASSIFIED AFAL-TR-78-176 NL

2 OF 2

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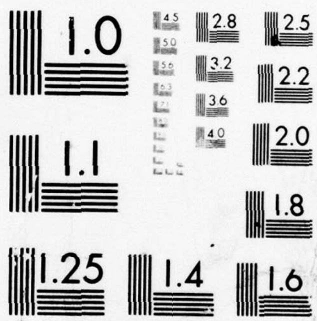

MICROCOPY RESOLUTION TEST CHART

NATIONAL BUREAU OF STANDARDS-1963-A

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      C=C+1
      IF(ID(A).LT.T) GO TO 5
      DATA(C)=1
      GO TO 10
5     DATA(C)=0
10    CONTINUE
      DATA(647)=0
      DO 100 J=1,647
      IF(DATA(J).EQ.1) GO TO 20
      IF(PRE.EQ.0) GO TO 100
      X(1)=I-1.
      X(2)=I-1.
      X(3)=I
      X(4)=I
      Y(1)=S
      Y(2)=J-1.
      Y(3)=J-1.
      Y(4)=S
      CALL TONE (X,Y,4,1)
      PRE=0
      GO TO 100
20    IF (PRE.EQ.0) GO TO 30
      GO TO 100
30    S=J-1
      PRE=1
100   CONTINUE
      CALL PLOT(0.,0.,+999)
      STOP
      END
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OUTPUT JOB 8900 9V GOGGANS 104 CARDS READ 7 PAGES PRINTED

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C      AREA CONSIDERS THE SCANED PICTURE NATURE OF DIGITIZED
C      MULTISPECTRAL SCANER DATA STORED ON MAGNETIC TAPE. AREA GENERATES
C      A HISTOGRAM OF NUMBER OF PIXELS ABOVE A SET THRESHOLD IN
C      CONTIGOUS  BLOCKS OF PIXELS VS. THEIR RELATIVE OCCURRENCE. AREA
C      MAKES THE SAME ASSUMPTIONS ABOUT THE DATA AS PROGRAM PLOTIT.
C      JOB CONTROL LANGUAGE MUST BE INCLUDED TO IDENTIFY UNIT 2 AS
C      THE TAPE CONTAINING THE FILE TO BE USED.
       INTEGER DATA(646),SB,GC(1000),THRES
       DIMENSION X1(1002),Y1(1002),ID(1938)
       INTEGER P,Q,R,S,T,U,X,Y,Z
       INTEGER B(16000 ),CN(16000)
       DIMENSION NGS(323),NGN(323),NGB(323)
       INTEGER OGS(323),OGN(323),OGB(323)
C***********  PARAMETERS WHICH CHANGE WITH DATA SETS  *****************
       THRES=184
       SB=3
       FILE=5.
       M=898
C**********************************************************************
C      THRES=INTEGER DATA VALUE USED AS THRESHOLD
C      SB=SPECTRAL BAND OF INTEREST  1,2,OR 3
C      FILE=FILE FROM WHICH DATA IS TAKEN   USED ONLY FOR LABELING
C       M=NUMBER OF RECORDS IN FILE
C**********************************************************************
       NO=0
       NB=0
       N=646
       DO 1 I=1,1000
1      GC(I)=0
       DO 60   I=1,M
       READ(2) ID
       NN=0
       K=1
       DO 3 J=SB,1938,3
       IF(ID(J).LT.THRES) GO TO 2
       DATA(K)=1
       GO TO 3
2      DATA(K)=0
3      K=K+1
       K=0
       DO 8 J=1,N
       IF (DATA(J).EQ.0) GO TO 7
       IF (K.EQ.1) GO TO 5
       NN= NN+1
       NGS(NN)=J
       NGN(NN)=1
       K=1
       GO TO 8
5      NGN(NN)=NGN(NN)+1
       GO TO 8
7      K=0
8      CONTINUE
       IF (NB.EQ.0) GO TO 10
        DO 9 Z=1,NB
9      B(Z)=0
10     IF(NN.EQ.0) GO TO 35
       DO 11 R=1,NN
11     NGB(R)=0
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      DC 30 P=1,NN
      IF(NO.EQ.0) GO TO 25
      DO 20 Q=1,NO
      IF(NGS(P).GT.OGS(Q)) GO TO 12
      U=OGS(Q)-NGS(P)
      IF(U.GT.NGN(P) ) GO TO 20
      GO TO 15
12    U=NGS(P)-OGS(Q)
      IF(U.GT.OGN(Q) ) GO TO 20
15    IF(NGB(P).EQ.0) GO TO 17
      IF (NGB(P).EQ.OGB(Q)) GO TO 20
      S=OGB(Q)
      T=NGB(P)
      DO 16 R=1,NO
      IF(CGB(R).NE.S) GO TC 16
      OGB(R)=T
16    CONTINUE
      CN(T)= CN(T)+CN(S)
      CN(S)=0
      GO TO 20
17    NGB(P)=OGB(Q)
      S=OGB(Q)
      CN(S)=CN(S)+NGN(P)
      B(S)=1
20    CONTINUE
25    IF(NGB(P).NE.0) GO TO 30
      NB=NB+1
      IF(NB.LT.16000) GO TO 27
      WRITE(6,26)
26    FORMAT('0','NUMBER CF BLOCKS DIMENSION EXCEDED')
       STOP
27    NGB(P)=NB
      B(NB)=1
      CN(NB)=NGN(P)
30    CONTINUE
35    IF(NB.EQ.0) GC TC 41
      DO 40 Y=1,NB
      IF(B(Y).EQ.1) GO TO 40
      IF (CN(Y).EQ.0) GO TO 40
      X=CN(Y)
      IF(X.LT.1000) GO TO 37
      X=1000
37    GC(X)= GC(X)+1
      CN(Y)=0
40     CONTINUE
41    IF(NN.EQ.0) GO TO 55
      DC 50 Y=1,NN
      OGS(Y)=NGS(Y)
      OGN(Y)=NGN(Y)
50    CGB(Y)=NGB(Y)
55     NO=NN
60     CONTINUE
      IF  (NB.EQ.0)  GO TO 80
      DO 75 I=1,NB
      IF(CN(I).EQ.0) GO TO 75
      Z=CN(I)
      IF(Z.LT.1000 ) GO TO 70
      Z=1000
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70      GC(Z)=GC(Z)+1
75      CONTINUE
80      CONTINUE
        PCOUNT=0
        DO 83 I=1,1000
83      PCOUNT=PCOUNT+GC(I)
        DO 90 I=1,1000
        X1(I)=I
        IF(GC(I).EQ.0) GO TO 85
        Y1(I)=GC(I)/PCOUNT
        GO TC 90
85      Y1(I)=0
90      CONTINUE
        NPS=200
        VALUE=THRES
        K=NPS+1
        DO 100 I=K,1000
        IF(Y1(I).EQ.0.) GO TO 100
        WRITE(6,105) I,Y1(I),GC(I)
100     CONTINUE
        WRITE(6,110) PCOUNT
        WRITE(6,120) SB,FILE
105     FORMAT(' ','I= ',I4,' Y(I)= ',E9.2,' G(I)= ',I3)
110     FORMAT('0','PCOUNT = ',F9.2)
120     FORMAT('0','SB= ',I2,' FILE= ',F4.2)
        SB1=SB
        CALL LION(X1,Y1,NPS,VALUE,FILE,SB1)
        STOP
        END
C
C
C
C
        SUBROUTINE LION(X,Y,NPS,VALUE,FILE,SB)
C**************LION GENERATES ALL AXIS,SCALING, LABELING AND PLOTING
C               NECESSARY FOR MAKING HISTCGRAMS ***************************
        DIMENSION X(1002 ),Y(1002 ),ID(1938)
         CALL PLOTS(0,0,0)
        CALL PLOT(0.,1.,2)
         CALL NUMBER(0.0,9.5,.35,VALUE,0.0,-1)
        CALL NUMBER(0.,9.,.35,FILE,0.,-1)
        CALL NUMBER(0.,8.5,.35,SB,0.,-1)
        CALL PLOT(3.,1.25,-3)
        CALL SCALE(Y,5.,NPS,1)
        CALL SCALE(X,7.0,NPS,1)
        CALL AXIS(0.,0.,'RELATIVE OCCURRENCE',+19,5.0,90.,Y(NPS+1),
       @ Y(NPS+2) )
        CALL AXIS(0.,0.,'NUMBER OF PIXELS IN BLOCK',-25,
       @7.,0.,X(NPS+1),X(NPS+2))
        CALL LINE(X,Y,NPS,1,0,0)
        CALL PLOT(10.,-1.25,-3)
        CALL PLCT(0.,1.,2)
        CALL PLOT(0.,0.,+999)
        RETURN
         END
OUTPUT     JOB 8907    9V    GOGGANS              188 CARDS READ      8 PAGES PRINTED      0 CARDS PUNCHED

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```
      DO 30 P=1,NN
      IF(NO.EQ.0) GO TO 25
      DO 20 Q=1,NO
      IF(NGS(P).GT.OGS(Q)) GO TO 12
      U=OGS(Q)-NGS(P)
      IF(U.GT.NGN(P) ) GO TO 20
      GO TO 15
12    U=NGS(P)-OGS(Q)
      IF(U.GT.OGN(Q) ) GO TO 20
15    IF(NGB(P).EQ.0) GO TO 17
      IF (NGB(P).EQ.OGB(Q)) GO TO 20
      S=OGB(Q)
      T=NGB(P)
      DO 16 R=1,NO
      IF(OGB(R).NE.S) GO TO 16
      OGB(R)=T
16    CONTINUE
      CN(T)= CN(T)+CN(S)
      CN(S)=0
      GO TO 20
17    NGB(P)=OGB(Q)
      S=OGB(Q)
      CN(S)=CN(S)+NGN(P)
      B(S)=1
20    CONTINUE
25    IF(NGB(P).NE.0) GO TO 30
      NB=NB+1
      IF(NB.LT.16000) GO TO 27
      WRITE(6,26)
26   1FORMAT('0','NUMBER OF BLOCKS DIMENSION EXCEDED')
       STOP
27    NGB(P)=NB
      B(NB)=1
      CN(NB)=NGN(P)
30    CONTINUE
35    IF(NB.EQ.0) GO TO 41
      DO 40 Y=1,NB
      IF(B(Y).EQ.1) GO TO 40
      IF (CN(Y).EQ.0) GO TO 40
      X=CN(Y)
      IF(X.LT.1000) GO TO 37
      X=1000
37    GC(X)= GC(X)+1
      CN(Y)=0
40     CONTINUE
41    IF(NN.EQ.0) GO TO 55
      DO 50 Y=1,NN
      OGS(Y)=NGS(Y)
      OGN(Y)=NGN(Y)
50    OGB(Y)=NGB(Y)
55     NO=NN
60     CONTINUE
      IF  (NB.EQ.0)  GO TO 80
      DO 75 I=1,NB
      IF(CN(I).EQ.0) GO TO 75
      Z=CN(I)
      IF(Z.LT.1000 ) GO TO 70
      Z=1000
```